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U. S. DEPARTMENT OF AGRICULTURE,

WEATHER BUREAU.

# CLIMATE:

## ITS PHYSICAL BASIS AND CONTROLLING FACTORS.

BY

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WASHINGTON:
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1904.

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## LETTER OF SUBMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
WEATHER BUREAU,
*Washington, D. C., May 11, 1904.*

Hon. JAMES WILSON,
*Secretary of Agriculture.*

SIR: I have the honor to recommend that the inclosed article on Climate, written by me for the Encyclopedia Americana, be printed as a bulletin of the U. S. Department of Agriculture, Weather Bureau. The information contained in the article will doubtless be of value to the younger observers of the service, and to the layman who is not an expert in meteorological science.

Very respectfully, your obedient servant,

WILLIS L. MOORE,
*Chief U. S. Weather Bureau.*

Approved:
JAMES WILSON,
*Secretary.*

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## CLIMATE.

From the Greek word κλίμα, a slope or inclination. The term was used to denote the effect of the oblique rays of the sun on the temperature of the earth and its atmosphere. To-day it is applied to the sum of the atmospheric conditions as recorded for a long period of time; or, in other words, it is the totality of weather, while "weather" is the physical condition of the atmosphere at a given time, or during a limited period.

One may well speak of the weather to-day, or of last month, of some past year; but not of the climate of a day, a month, or a year. The climate of a place is ascertained by a study of its continuous weather records for a long period of years—the atmospheric pressure, the temperature, the rainfall and snowfall, the time and frequency of frost, the extremes of heat and cold, the direction and velocity of the wind, the amount of air that flows from the different points of the compass, the amount and the intensity of sunshine, the humidity and transparency of the atmosphere, and its electrification.

The study of the causes of the weather and of the laws of storms constitutes that branch of science known as meteorology; climatology is to be considered as a subdivision of meteorology.

Climates may be broadly divided into marine, continental, mountain, and plain, with the many variations produced as these conditions gradually or precipitately shade off the one into the other.

*Basis of climate.*—If the axis of the earth's rotation were perpendicular to the ecliptic (the plane of its orbit) there would be no seasonal changes, for the rays of the sun would fall upon every point on a parallel of latitude with the same angle of incidence on each day of the year. There would be but one season at any place and it would never end, and there would be little variation in the intensity of storms. But as the axis of the earth is inclined at an angle of 23.5° to the plane of its orbit, and as the direction toward which it points remains

nearly constant, there are but two days in each year when both hemispheres (north and south) are exactly one-half in sunshine and one-half in darkness, i. e., at the vernal and autumnal equinoxes, when the sun crosses the equator. At all other times, in each hemisphere, the angle at which the sun's rays strike the earth, the depth of the air through which they pass, the length of the day, and the proportions of each hemisphere immersed in sunlight, are increasing or decreasing. As these four conditions increase in the Northern Hemisphere after the vernal equinox the summer grows upon us, reaching its greatest degree of heat about four weeks after the summer solstice. The lag of temperature is due to the fact that the atmosphere, being heated mainly by radiation from the earth and comparatively little by the direct action of the solar rays, does not attain its greatest heat until after the land and water have reached their maximum temperature and in turn have communicated this heat to the air above. Up to June 21, or the summer solstice, the Northern Hemisphere receives each day more heat than it loses, otherwise it could not gain in temperature; after the solstice the sun each day at meridian is found to have receded a little to the south. At places north of the Tropic of Cancer its rays fall with increasing obliquity and pass through a greater depth of air, and impinge for a less time each day, so that within a few weeks the earth begins to radiate more heat each day than it received. The maximum heat of summer occurs, on the average, when the loss of heat from the earth is just equal to that gained during the day from the sun. This, as previously stated, occurs several weeks after the sun is well on its way southward. About September 21 the autumnal equinox occurs, when the sun crosses the equator, and, as at March 21, the days are of equal length at all latitudes of both hemispheres. On or about December 21—the winter solstice—the sun is farthest south, and the same conditions prevail in the Southern Hemisphere that prevailed in the Northern Hemisphere on June 21. North of the equator the sun is now least effective; its rays reach the earth at the lowest angle through the greatest depth of air, and they are operative for the fewest hours during each day, of any portion of the year, but the greatest cold does not occur. This comes about four weeks later, when the increasing heat received each day by the earth from the sun is just equal to that lost by radiation.

The effect of latitude will be understood by reference to the following figure:

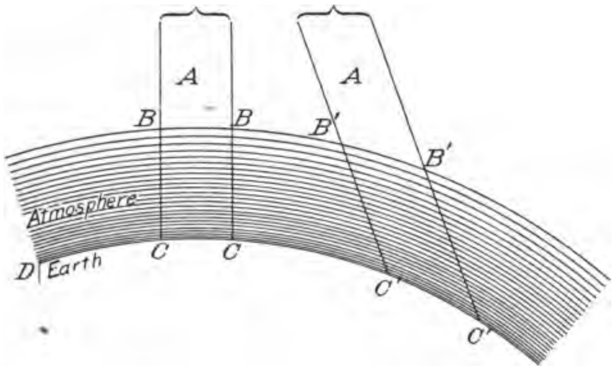


FIG. 1.

As the latitude increases, the rays of the sun will fall with increasing obliquity, and they lose in power by being spread over a larger surface, and by traversing a greater depth of air, which absorbs more of their heat.

The same beam *A*, "when the sun is vertical, is spread over a surface such as *C C*. When the sun is inclined at an angle as shown in the figure, the beam is spread over a surface, *C′ C′*, which is somewhat greater than the first, and it passes through a column of air, *B′ B′ C′ C′*, greater than that of *BBCC*. The intensity of insolation at midday decreases approximately as the cosine of the latitude."

Near the equator the sun's rays at midday fall perpendicular to the surface of the earth, and there is virtually no change in the length of the day, and consequently there is little variation in the daily or seasonal temperature. As the variation in the length of the day increases with the latitude, there are regions, in the temperate zone, where the length of time that the sun's rays fall upon the earth each day more than compensates for their obliquity. On this account the interior of continents may have at midday a higher temperature than prevails at the equator.

Solar energy is about 7 per cent greater at perihelion (the point in the earth's orbit nearest the sun) than at aphelion (the point farthest away). As perihelion occurs in December, or the summer time of the Southern Hemisphere, and aphelion in its winter, that region has a greater range in the intensity of solar insolation than the Northern Hemisphere. If the land

surfaces of the two hemispheres were equal in area, the southern would have colder winters and warmer summers than the northern, and this is the case in portions of the Southern Hemisphere where the land area is large. But the great capacity of water for heat, and the slowness with which it radiates the same, modifies seasonal extremes that otherwise would be much greater.

*Variations in climate.*—If the earth were all water or all land, and if the land were everywhere of the same elevation, most of the factors that cause variations in climates—often considerable for regions closely contiguous—would be eliminated from the equation. Every point on the same parallel of latitude would have the same mean annual temperature, and the same average heat in summer and the same average cold in winter. New York and London, separated by eleven degrees of latitude, would not, as now, have about the same mean annual temperature. If it were all water, there would be no such extremes of heat and cold as we now know. It is probable that a thermometer exposed in the shade 4 feet from the surface of the earth would not anywhere—even at the equator—ever register above 90° F.; there would be no frost within 35° or 40° of the equator, and zero temperatures would be recorded only in regions within 30° of the poles. If it were all land the heat would be much more intense than now in the Tropics, and in the temperate and frigid zones the heat of summer and the cold of winter would reach extremes unknown at this time.

All the anomalies of climates are caused by the different specific heat capacities of land and water; their different powers of conduction and radiation; the irregular distribution of these two surfaces; the widely-varying elevations of the land; the trend of mountain ranges; the prevailing direction of the winds, and the carrying of large quantities of heat by ocean currents from the equator toward the poles, and the relative quantities of cloud and rain or snow. It is germane to a proper understanding of climate to know something in detail of the manner in which the air is heated. At 100 or 200 miles above the earth's surface there is only the hypothetical ether, which, while too tenuous to be detected or measured by any methods or appliances so far known, is supposed to be the medium that transmits solar energy to the earth and diffuses it through space. This energy, coming in many different wave lengths and with widely-varying intensities

of vibration, produces several different phenomena as it is absorbed by or passes through the air, or as it impinges on the surface of the earth. The waves differ in their effects on different objects, depending on the length and the absorptive response of the substances upon which they fall. The waves have heating, lighting, and chemical effects simultaneously in themselves, and it is only the nature of the objects upon which they fall that tends to differentiate them. The atmosphere, even at the surface of the earth, absorbs but a small part of the heat waves. They, therefore, reach the earth and warm its surface; and the earth in turn, by radiation, convection, and conduction, sends back into the air long heat waves, which, unlike the shorter solar waves, are readily absorbed by the atmosphere. The atmosphere is thus warmed from the bottom upward. This accounts for the perpetual freezing temperatures of very high mountain peaks, although they are nearer the sun than are the bases from which they rise. At the height of one mile in free air the temperature is about the same at midday as at midnight. Only during recent years have we begun to realize how extremely thin is the stratum of air next the earth that has sufficient heat for the inception, growth, and maturity of both animal and vegetable life. The raising of the thermometer shelter at the New York City observatory from an elevation of 150 feet above the street to an elevation of 300 feet, has caused an apparent lowering of the mean annual temperature of 2.5° F. On the hottest day in summer, if one could be lifted up to a height of only 1000 feet in free air, he would find a marked change in temperature. The United States Weather Bureau at 16 stations made a total of over 1200 kite observations in the United States in 1897. They showed an average decrease of 7.4° F. for the first 1000 feet of ascent during the warm months, and when the observations were taken near the hour of daily maximum heat the decrease was frequently as much as 15°. At the height of 6 miles the cirrus clouds common to this level are, on account of the low temperature, always composed of minute ice spiculæ, never of watery droplets like the lower cumulus clouds. In the middle latitudes of both hemispheres the air at this height is ceaselessly rushing toward the east, passing uninterruptedly over the cyclonic and anticyclonic systems that cause our storms and cold waves at the surface of the earth. Glaisher and an assistant ascended to a height of about 30,000 feet.

They suffered greatly from the cold, which measured many degrees below zero, although the time of year was September 5. At the height of 6 miles the average temperature, determined by many balloon ascensions is about —60° F.

The difference between continental and marine climates is marked. The same amount of heat will raise the temperature of a land surface four times as high as it will raise that of a water surface. Land is a good absorber and a good radiator, but it is a poor conductor and a poor reflector. The absorbed heat does not penetrate into the ground to any great depth. The land, therefore, retains its absorbed heat near the surface and quickly and freely radiates that which it has absorbed. These conditions give to large land surfaces much higher temperature during the day and much lower temperature during the night than obtain over a water surface of the same latitude and much colder winters and much warmer summers. As an illustration, it may be stated that the Bermuda Islands, in the North Atlantic Ocean, have a mean daily range of temperature of only 10° F., and an annual range of only about 50°; while Memphis, Tenn., near the same latitude, in the interior of a large continent, has a daily range of 17° and an annual range of 112°. At Memphis a temperature of 104° has been recorded in summer and —8° in winter. At Bermuda the temperature generally reaches 90° during the summer, but very rarely exceeds that figure, while temperatures below 45° are also very infrequent. The two places are typical of continental and of marine climates. All regions bordering closely on the sea partake of both climates, the predominating one being determined by the direction in which the coasts trend, their elevation, and the direction and force of the prevailing winds.

In the middle latitudes of both hemispheres the prevailing winds are from the west, and, therefore, continents lying in these regions have a marine climate in their western costal regions, where the air moves from the water to the land, and nearly continental climate in their eastern costal regions, where the general movement of the air is from the land to the sea.

The distance to which moist and equable air conditions extend inland is determined by the elevation of the land and its trend relative to the incident winds and the proximity of mountain ranges. The humid air from the Pacific meets the lofty range that skirts the western shore line of both North

and South America; it is forced up the mountain side until the cold of high elevation and the cooling of the air by expansion as it ascends cause it to precipitate its moisture, mostly upon the western side of the mountain, and it passes to the interior of the continent bereft of that life-giving moisture which, were it not for the intervention of the mountains, would spread a mantle of luxuriant vegetation 1000 miles inland. If the disintegrating effects of temperature and rainfall had worn down the Sierras, the Plateau, and the rugged crags of the Rocky Mountains to the height of the Appalachians, the vaporous atmosphere of the Pacific would flow eastward far more freely than now, and meet that which, by the convectional action of cyclones, is frequently carried from the Atlantic Ocean and the Gulf of Mexico inland to the Mississippi Valley; then rain would be more abundant and the whole of the United States would have arable land.

To give a further idea of the effect of mountain systems on the climates of continents one needs only to reverse the conditions just mentioned; if the Appalachian Mountains were as high as the Rocky Mountains, and if they extended farther southward and bordered the Gulf of Mexico, then the Ohio River, the Mississippi, and the Missouri and their many tributaries would not exists, and the world's greatest granary would be a gray and nearly barren plain.

The specific heat of water is greater than that of almost any other substance. It requires 10 times the quantity of heat to raise a pound of water 1° than it does to raise a pound of iron 1°. Solar rays penetrate the sea to a considerable depth; they are quite uniformly absorbed by the stratum penetrated. In consequence of these laws and conditions a vast quantity of heat is stored by the ocean in the Tropics and slowly given to the air as the ocean currents carry the warm water toward the poles. In this connection the writer would correct what he believes to be an exaggerated popular idea relative to the effect of the Gulf Stream on the climate of Europe. The North Atlantic circulation, flowing northward on the western side of the ocean (except a southward current from Davis Strait that chills Labrador and somewhat affects the temperature of the New England coast), and southward along the coast of Europe, is many times more effective in modifying climate than is the Gulf Stream. That the western part of Europe is warmer, more humid, and subject to less radical

changes in temperature than equal latitudes in North America, except on the Pacific coast, is due primarily to the great ocean that lies on the west of Europe. Without ocean currents of any description this body of water would give to the air that moves from it to Europe a more equable temperature than is possessed by the eastern part of the North American Continent. Continents, therefore, partake largely of marine climates on their western borders, and principally of continental climates on their eastern borders.

Climate affects the health, happiness, and well-being of people more than any other condition that goes to make up their environment. Within the broad confines of the United States there are many, but not all, shades and varieties of climate. One of the questions most frequently asked is: "Where shall I find a climate possessing both dryness and equability of temperature?" To this interrogatory reply must be made that the ideal climate as regards equability of temperature and absence of moisture does not exist in the United States, but that the nearest approach to it will be found in the great Southwest.

The temperature of the Southwest is not equable in the sense of having an extremely small daily range, but it possesses the quality of annual uniformity in a greater degree than will generally be found elsewhere except on the seacoast, and there the humidity is great.

The most equable temperature on the globe will be found on the high table-lands and plateaus of the Tropics. Santa Fé dé Bogota, in the United States of Colombia, has an average temperature of about 59° F. for all months of the year, and the range for the entire year is less than is often experienced in a single day in some parts of the middle latitudes. But while the ideal temperature may be found on the higher elevations of the Tropics, the rainfall is much greater and more continuous than in this country.

The temperature of a place depends chiefly on three conditions—latitude, elevation, and contiguity to large bodies of water. At sea level in the Tropics extreme conditions of heat and moisture produce very great physical discomfort. But even under the equator it is possible to escape the tropical heat of low levels by ascending from 4000 to 6000 feet. In the economy of nature there is a certain limit beyond which the two extremes, dryness and equability of temperature, can

not coexist; thus we may find a region so deficient in moisture as to satisfy the requirements of the case, but the very lack of moisture is a condition that facilitates radiation and thus contributes to great extremes of temperature. Regions may be found, as on the lower Nile, where there is a lack of rainfall coupled with a high and moderately uniform temperature. The mean winter temperature of Cairo, Egypt, is 56° F.; mean summer temperature, 83°; a range from winter to summer of 27°. The mean winter temperature of Phoenix, Ariz., is 52°; mean summer temperature, 87°; a range of 35°. It is by no means difficult to find a counterpart of the far-famed Egyptian climate in the great Southwest.

The dryness of the air and the clearness of the sky are the conditions upon which daily ranges of temperature depend; the greater these, the greater the range of temperature from day to night. While a high summer temperature is characteristic of the Southwest and other portions of the Rocky Mountain Plateau, it is a fact that the sensation of heat as experienced by animal life there is not accurately measured by the ordinary thermometer. The sensation of temperature which we usually refer to the condition of the atmosphere depends not only on the temperature of the air, but also on its dryness and the velocity of the wind. The human organism, when perspiring freely, evaporates the moisture of its surface to the dry air of the interior arid regions, and thus lowers its temperature and prevents sunstroke, which, in the more humid regions from the Mississippi Valley eastward, occur in great number with the air temperature much less than obtains in the West.

The meteorological instrument that registers the temperature of the evaporation, and thus in some measure the actual heat felt by the human body, is the wet-bulb thermometer. The latter, as indicated by its name, is simply an ordinary mercurial thermometer whose bulb is wetted with water at the time of observation.

*Effect of climate on the races.*—Climate is the most potent of any factor in the environment of races. It is climate and soil, plus heredity and form of government, that produces either vigorous or weak peoples. In this respect it is a question if the United States does not possess a constant potential that, all other conditions being equal, places it in a class by itself.

Climate, soil, and good heredity may produce a race large

of statue and of great physical endurance, but unless such a people exist under a liberal form of government, in which public education is fostered and the arts and sciences taught, it is unable to employ its strength in those lucrative vocations that alone give a high per capita of wealth; and wealth means power. It is also weak in defending itself, either in war or in commerce, against a people of less numerical strength that is liberally educated, skilled, and humanely governed.

If one reads of the overthrow of political dynasties and the subversion of trade and commerce, it will occur to him that northmen have usually been conquerors. If we consider the invigorating effect of cold air and marked changes of temperature alone we might expect to find the strongest and most resourceful peoples inside of the Arctic Circle; and if we consider fruitfulness of soil alone we might reasonably expect to find the dominant peoples in the Tropics. But the fact is that the greatest human potentiality occurs somewhere between these two extremes. The boundaries can not be accurately determined by the naming of certain parallels of latitude, but a close approximation is made to the truth in the statement that the most vigorous people physically and the most resourceful mentally will be found in the most northerly regions that will produce not simply cereal crops, but an abundance of them.

The sweep of the cold wave, as it is known in the United States, is quite distinctly North American. Nowhere else on fertile plains, unless it be in Russia, does the temperature show such wide oscillation within such short periods of time, nor do the icy blasts sweep over such a broad area. It is probable that much of the physical and the intellectual energies that have caused the United States to excel in agriculture, in manufacturing, and in commerce, were produced by the invigorating effect of the cold, dry, highly electrified air of the North American cold wave. The anticyclonic systems of air that constitute cold waves have a marked downward component of motion. This motion brings from a considerable altitude to the surface of the earth some of the high electrical potential of the upper air, which is strongly stimulating to man and to other forms of animal life. These cold north winds have a much greater specific gravity than warm and humid winds, and this condition, added to the force with which they come, scatter and diffuse the befouled air near the surface of

the earth. Enough has been said to indicate that climate is nearly as important a part of the environment of animal life as it is of the vegetable existence, and that a wide range of annual temperature, if it be not so great as to limit the production of cereal crops, favors the development of strong races of men.

*Change of climate.*—Notwithstanding the popular notion to the contrary, there is reason to believe that there has been no appreciable change in the climate of any large area within the period covered by authentic history. Changes in the surface of the earth may be noted within the lifetime of an individual, that are thought to prove that a change of climate has taken place, when the alterations may be due to the persistent action of freezing, thawing, rainfall, and flood. Great changes have occurred during geologic periods, but it is the opinion of the writer that they take place so slowly that thousands of years must elapse before their effect is measureable.

*Effect of forests on climate.*—Extremes of temperature, both heat and cold, are slightly less over forests than over open regions, but the most important effect of forests on climate is the economic conservation of precipitation, diminishing the intensity of floods by restricting the flow-off, and by shading the snow deposited during the winter from the increasing sun of spring and early summer. More moisture is absorbed by the soil when it is covered by forest than when it is cleared of its forest cover, and it follows that deforestation, if extensive, may diminish the supply of springs and streams.

Investigations in Germany and in India seem to indicate that there is an appreciable increase in rainfall as a result of reforestation. In general, forest may be looked upon as the effect rather than the cause of rainfall.

*Climate and animals.*—The geographic distribution of animals is doubtless the outcome of definite laws—laws that stand in close relation with the past history of the earth through a large portion of geological time. What those laws are forms a subject of great importance in studies of evolution, a subject, it may be remarked, entirely too great to be adequately treated in the present connection. Naturalists are generally of the opinion that all animals have been produced from those that preceded them by some slow process of transmutation or development, and that this modification of animal forms took place very slowly, as evidenced by the fact that the historical

period of nearly 4000 years has hardly produced any perceptible change in a single species. That marked changes in the climate of the earth have occurred during the remote past there can be no doubt, and that those changes left a marked impress upon the fauna of the globe there can also be no manner of doubt. The great northern ice sheet and the accompanying cold of the glacial period, if it did not cause the extermination of the receding fauna, doubtles led to its migration to more congenial climates.

The part played in the faunal distribution of the globe by the present climate seems to be indirect rather than direct, although there are many facts which seem to point to a direct relation. While it is true that the fur-bearing animals of the frozen north are generally to be found in arctic regions, yet they send their representatives far into the temperate latitudes, and indeed into the borders of the regions inhabited by the more exclusively tropical species. On the other hand, the tiger, whose home is naturally associated with the hot districts of India and the Indian Archipelago, is equally at home in the elevated regions of the Caucasus and the Himalayas, where his footprints are not infrequently found impressed in fields of snow. Other groups of animals are more limited in their migrations. Some are so closely adapted to an arboreal life that they never stray far beyond the limits of forest vegetation, while others are so tolerant of climatic change that the limit of their possible range is conditioned only by the character and quanity of the food supply and the interposition of impassable physical barriers.

*Climate and plants.*—The factors necessary to the development of plant life are light, heat, soil, and moisture. The ideal conditions as regards these essentials do not usually obtain, or, if they do, multitudes of plants seek to take possession of the region, so that there is a continuous struggle for existence in which many more plants fail than succeed.

The climatic factors, heat and moisture, are combined in several ways in different parts of the globe, and these combinations give widely different vegetation; thus a maximum of heat and a minimum of water give desert conditions where only specially adapted plants can exist. If, on the other hand, a maximum of heat is combined with a maximum of water, the result will be vegetation such as exists only in the rainy tropics. The possible combinations of the two climatic fac-

tors are very numerous, as are also those of soil and the effects of animal life and human agencies. Yet the vegetation of the globe is susceptible of a fairly definite classification. Following Humbolt, and adopting such terms as express in a general manner the vegetation characteristic of each zone, we have the following classification:

| Zones of— | Average temperature. |
|---|---|
| | ° |
| 1. Palms and bananas | 78–82 |
| 2. Tree-ferns and figs | 73–78 |
| 3. Myrtles and laurels | 68–73 |
| 4. Evergreens | 60–68 |
| 5. Deciduous trees | 48–60 |
| 6. Conifers | 40–48 |
| 7. Lichens, saxifrages, and dwarf shrubs | 32–40 |
| 8. Lichens and mosses | 32 and below. |

While in a general way these zones stretch around the world in wavy belts, somewhat as do the isotherms, similar belts may be found encircling mountain peaks and chains with increasing altitude above sea level. Indeed, it is possible to pass successively from tropic to arctic vegetation on a single mountain peak in the Tropics.

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Bulletin No. 35—W. B. No. 322.

U. S. DEPARTMENT OF AGRICULTURE,

WEATHER BUREAU.

# LONG-RANGE WEATHER FORECASTS.

Prepared under direction of WILLIS L. MOORE, Chief U. S. Weather Bureau,

BY

E. B. GARRIOTT,
PROFESSOR OF METEOROLOGY.

UNITED STATES DEPARTMENT OF AGRICULTURE

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# LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
WEATHER BUREAU,
*Washington, D. C., October 28, 1904.*

Hon. JAMES WILSON,
*Secretary of Agriculture, Washington, D. C.*

SIR: I have the honor to transmit herewith a paper on the subject of long-range forecasts, by E. B. Garriott, professor of meteorology, and to recommend its publication as a bulletin of the Weather Bureau. It includes a valuable paper by Prof. C. M. Woodward, of Washington University.

The first chapter, by Professor Garriott, presents a verification of the work of the most prominent of the so-called long-range weather forecasters in the United States that shows conclusively the fallacy of their predictions. The second chapter, by Professor Woodward, shows the impossibility of basing weather predictions on planetary influences. This chapter was published by Professor Woodward in 1875 in Ware's Valley Monthly, and Mr. Tice, whose theory of planetary equinoxes is discussed and refuted, was the predecessor of a long-range weather forecaster who is now operating in St. Louis, Mo.

The remainder of the paper is devoted largely to the discussion of the subject by many of the leading meteorologists of the world. It reviews the literature of long-range weather forecasts, and quotes the opinions of leading scientists regarding the practicability of long-range work. It refers to theories regarding weather periodicities depending upon lunar and planetary influences; summarizes results obtained by comparisons of maximum and minimum sun-spot periods with the phenomena of the earth's atmosphere; states that the next advance in meteorological science must result from extensive research in solar physics and terrestrial magnetism and comparison of solar and terrestrial phenomena; assumes that advances in the period and accuracy of the official weather forecasts depend largely upon a study of atmospheric pressure over great areas, and a determination of the influences that occasion normal and abnormal distribution of the greater atmospheric areas.

The success of the United States Weather Bureau in making conservative forecasts of the weather two or three days in advance has created the hope in the minds of the people that it may be possible to foresee the character of the weather for the coming month or season. All scientific men know that at present it is impossible to gratify this wish, and the Government experts so inform all those who make inquiry. But the mistaken investigator of little knowledge, the pseudo scientist and the astrologer, see their opportunity and at once

step into the breach and sell spurious long-range forecasts to a public rendered credulous by the success of the Government scientists. The abuse of the public confidence has become so great that I have thought it justifiable to present to the reader indisputable evidence of the injurious character of monthly or seasonal forecasts.

It is the opinion of the leading meteorologists of the world that public interests are injured by the publication of so-called long-range weather forecasts, especially by such predictions as relate to severe storms, floods, droughts, and other atmospheric disturbances of a dangerous or damaging character. The publication of monthly forecasts has reached such proportions that it is deemed advisable to inform the public as to their harmful character. Some monthly forecasters may be honest, and may, in their ignorance, attach undue importance to storms that accidentally coincide in time of occurrence with certain relative positions of the moon, or with periods of increase or decrease in sun spots, or apparent variations in the solar intensity. To men of this class the occurrence of a storm within the broad area of the United States on or near the day for which they have predicted a storm confirms, in their minds, the value of their system of prediction. They may believe that they have discovered a physical law or a meteorological principle that has not been revealed to astronomers, meteorologists, or any other class of scientific investigators, but the publication of predictions that, by reason of their inaccuracy are positively injurious to agricultural, commercial, and other industrial interests casts a doubt upon the honesty of their makers.

As a result of my personal verification of the work of long-range weather forecasters, some of whom have so far gained the confidence of the rural press as to receive liberal compensation for their prediction, I am led to the conclusion that these forecasters do positive injury to the public at large. It is to be regretted that so many newspapers not only give space to these harmful predictions, but actually pay for them. Forecasts of this description may properly be classed with advertisements of quack medicines—they are both harmful in the extreme.

I hope the time will come when it will be possible to forecast the weather for coming seasons, to specify in what respect the coming month or season will conform to or depart from the weather that is common to the month or season, but that time has not yet arrived, and I believe that we will serve the public interests by teaching the people the limitations of weather forecasting, and by warning them against imposition.

Very respectfully,

WILLIS L. MOORE,
*Chief United States Weather Bureau.*

Approved.

JAMES WILSON,
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# VERIFICATION OF LONG-RANGE WEATHER FORECASTS.

The proof of the forecast is in its verification. Measured by this standard, long-range weather forecasts have an experimental value only, a value that does not justify their employment in the actual work of forecasting for specified dates and places.

Meteorologists who have conceived theories for long-range forecasting, or who have tested theories advanced by others, have applied to the theories the test of facts that are presented by meteorological records, and the results have been negative. Men who issue fake forecasts have adopted an opposite method. They have carefully ignored and concealed facts and have depended upon advertisements of occasional successes that will inevitably occur in any system of chance, and their success may be measured by the extent to which they can impose upon the credulous and the ignorant.

As a rule, it is impossible to subject the rambling and indefinite statements of the long-range weather forecaster to a verification. In the summer of 1903, however, one of these forecasters was induced to submit to the Weather Bureau some forecasts for verification. The forecasts consisted of an enumeration of certain dates around which "storms would cluster and develop great intensity." The periods, or dates, of maximum storm force as forecast and the actual weather conditions that appeared on the dates were as follows:

*August 11, 1903.*—On this date there were no storms in any part of the United States, and no extraordinary weather conditions were manifested at any point within the region of observation, except that a tropical disturbance of small diameter was apparently moving westward south of Jamaica, West Indies. As the forecast did not specify in what part of the Northern Hemisphere the storms would reach their maximum intensity, it can not be considered that the occurrence of this storm in any way verified the forecast.

*August 24, 1903.*—On this date no evidence could be discovered of an increase of storm force, the usual stagnant summer conditions prevailing in all parts of the United States.

*September 7, 1903.*—On this date the weather conditions were not unusual; there were no storms of marked energy in any part of the country. A disturbance covered the northern Rocky Mountain region and the upper Missouri Valley, but it moved northeastward and did

not in any way affect the region to the eastward. There was nothing unusual in the disturbance above mentioned. A storm of considerable energy developed in the vicinity of the Bahamas on September 10 and persisted in the vicinity of the Gulf region until the 15th. No mention of this disturbance was made in the forecast.

*September 21, 1903.*—On this date, likewise, the usual weather conditions prevailed in all parts of the region of observation.

*October 6, 1903.*—On this date a depression of considerable magnitude covered the eastern slope of the Rocky Mountains. It moved eastward and developed into a severe storm on the Atlantic coast on the 9th and 10th, three days after the date set by the forecaster.

*October 19, 1903.*—On this date the usual October weather prevailed in all parts of the United States. There was not the slightest evidence of increased storm energy on this date.

This is a plain statement of the weather conditions experienced on the dates when, according to the forecasts, the most severe storms of recent years were to occur. Let us quote of the forecasts:

> Clustering around September 7 and 21, October 5 and 20 will come some of the most severe storms of recent years. These will be so general all around the earth that I advise all to be on guard near the dates named. Storms miss ninety-nine out of one hundred places, but you will at least read of tornadoes, hurricanes, cloud-bursts, electrical storms, seismic disturbances in nearly all sections where these sometimes occur.

Considerable time has already been devoted to an examination of forecasts of this character, and the results thus far obtained show that the forecasters possess no knowledge that would justify them in the making of predictions.

To a long-range forecaster the occurrence of a thunderstorm or an electrical disturbance in some remote corner of the globe during one of his "storm periods" will justify his forecasts.

The matter of verifying the forecasts of this long-range forecaster was again taken up during the present year, the forecasts used being those that appeared in the public press. It was found that one element only was stated in language that would permit a verification—the temperature.

With the approval of the forecaster the forecasts that applied to the region of the ninetieth meridian were alone considered, and these were verified by the records of the Weather Bureau office at Springfield, Ill. The verifications showed that, considering the law of chance, the times when the actual temperature conformed, even in a general way, to the forecasts were surprisingly few. In fact, the forecasts of warm and cold waves, if reversed, would result in a higher percentage of verification.

Forecasts of this character can be of no value to agricultural, commercial, or maritime interests. On the contrary they are misleading, and if given credence are calculated to result in positive injury. Farmers, merchants, and mariners who keep pace with modern progress do not give credence to this class of forecasts. A long-range forecaster who receives remuneration for his work is simply catering to a class of readers who are deficient in a knowledge of the present status of popular science.

There is another long-range weather forecaster who draws his support from the American public who does not depart in any essential manner from the methods employed by the one above referred to. His statements are based upon a consideration of the moon's path with reference to the ecliptic and the equator, the phases of the moon, disturbing causes due to movements and positions of the planets, etc.; in fact, a conglomerate gathering together of all imaginary and obsolete notions regarding weather causes that are calculated to mystify credulous and uninformed people. He predicts the general character of a month with a consciousness that the forecast will be verified in at least some part of a great unspecified area. He then outlines "storm periods," with intervals of two or three days, which are covered by a margin that is claimed for verification purposes, and verifications are claimed if storms occur during the periods or in the intervals in any part of the United States, and, at times, in the Northern Hemisphere. This system of forecasts and verifications admits of no failures. So much for his regular forecasts. Let us now examine some of his special, emphasized predictions:

In the early part of April, 1904, a tornado and severe storms were scheduled in various western papers over the name of this forecaster to appear "right after April 17." The storms failed to materialize in the United States during the period specified. Reports from remote parts of the Northern Hemisphere have not, however, been received, so it is possible that a justification of the forecast will be claimed. Aside from platitudes regarding average weather conditions that prevail in April, he announced that—

> One of the most decided, and perhaps violent, storm periods of the month extends from about the 25th to the 29th.

In the United States the period was a quiet one, and the disturbances that appeared (and one or more surely would appear within the area of the United States during the period specified) were not attended by "very general and violent storms, destructive hailstorms, and abnormal downpours of rain," which, according to the detailed forecast, should have been experienced.

which falls under the first blow, it is due to science, and above all it is due to the friends and patrons of Mr. Tice, that the exact truth be told.

It should be premised that astronomers and physicists have during the last half century been carefully observing and tabulating all sorts of phenomena previously considered purely fortuitous. Schwabe's discovery of the regular recurrence of sun-spot periods was the first fruit of such systematic effort. Careful analysis of sun-spot observations since 1826 shows a period of 11.11 years between two successive times of maximum frequency. Next it was found that exactly the same period holds good for special magnetic disturbances or storms, and that the times of maximum and minimum sun-spot frequency agree with the times of maximum and minimum magnetic disturbance. These complete coincidences are what Mr. Tice calls "incontestable facts." Next it was found by observers in the East and West Indies that the years in which the sun spots were the most frequent, and the earth was electrically most excited, were also the years in which hurricanes were the most terrible and most numerous.[b] Various other phenomena seemed to be periodic, agreeing closely with the above.

Such striking coincidences did not fail to suggest a common cause, or, at least, the relation of cause and effect. Jupiter makes a complete revolution in his orbit in 11.86 of our years, a period only slightly larger than that mentioned above. This coincidence and some others affecting the planets have been much discussed, and I can not better show how they have struck the minds of astronomers than by quoting a few words from Mr. Richard A. Proctor's work on The Sun:

> As respects the sequent series of researches by which Messrs. De La Rue, Stewart, and Loewy have endeavored to estimate the influence of the planets upon solar spots, it is to be remarked that the evidence adduced seems as yet not wholly decisive. They believe that it has been rendered probable that Venus exerts a special influence on the solar spots, and that the conjunctions of the planets also affect importantly the condition of the solar photosphere. There is room, in my judgment, for some doubt as to the justice of either conclusion. It should not be forgotten that the planetary system represents so many periodic relations as to render it almost certain that any periodic changes in the sun's condition may be associated statistically with some period of planetary motion—siderial, synodical, nodical, or otherwise. There is a remark toward the close of Carrington's volume on the solar spots which bears very significantly on this subject. After exhibiting the relation between the phenomena of solar spots, as tabulated by Professor Wolf, and Jupiter's variations of distance, he says that "from the year 1870 there is a very fair agreement between the maxima of frequency and maxima of Jupiter's radius vector, and between minima and minima;" but "in the two periods which precede that date

[[b] Recent studies show no relation between sun spots and hurricanes.—Note by editor.]

there appears to be a total disagreement." "It is important," he then adds, "to see before us an instance in which *eight consecutive cases of general but imperfect agreement between the variation of two physical phenomena are shown to be insufficient to base any conclusions upon*, at the same time that they powerfully stimulate further inquiry with the view of ascertaining whether the discrepancy may admit of future explanation. I would by no means be understood to imply, however, that I regard the conclusions of Messrs. De La Rue, Stewart, and Loewy respecting the influences exerted by the planets on the solar phenomena as inadmissible. On the contrary, I regard them as, on the whole, the most probable yet advanced. Based as they are on observed facts and on statistical relations, they are worthy of the most attentive consideration. They do not seem to me, however, to be by any means *demonstrated*, nor are they so regarded (it is proper to add) by their propounders."

I have quoted fully for two reasons: First, to show that as far as Jupiter is concerned, the main coincidence seems to be between the times of minimum spot frequency and Jupiter's perihelion, and between the times of maximum spot frequency and his aphelion; and, secondly, for the purpose of showing how cautious scientific men are about assuming things to be demonstrated.

Now, of course the most of this was well known to Mr. Tice when he began looking for the "great cycle."[a] He had observed that some phenomena were periodic, and he thought that all might be so, and he hoped by establishing a great meteorological cycle he would have the key for explaining all atmospheric phenomena. So great was his anxiety to secure exact coincidence between the periods I have mentioned, that in spite of some very sensible remarks against the practice of obliterating all individual phenomena by resorting to very general averages, he, according to his own confession, "lumped" the phenomena of sun spots, hurricanes, and magnetic storms with others of less frequency, and succeeded in getting an *average* of 11.83 years. This differs from Jupiter's period but about 0.03 of a year; this he jumped, and adopted Jupiter's period of revolution as the "great cycle." It seems as though this forcing process would be suicidal to any theorizer, for as the period of sun-spot phenomena is beyond all question almost exactly 11.1 years, Mr. Tice's "great cycle" is in excess of that fully three-fourths of a year, an amount which would change exact agreement into total disagreement in five or six periods; and this is just the fate of Mr. Tice's cycle. He seems not to have remembered that finding the average of several unequal periods does not after all make those periods equal.

The point Mr. Tice reaches is that all atmospheric phenomena are

[a] Although he says: "I *projected* the hypothesis that Jupiter in some unknown way was the cause of the perturbations" (p. 11), I should say here that in all the quotations I make from Professor Tice's book I shall follow his exact language, including punctuation and the use of capitals. The italics, however, will be mine.

produced by planetary equinoxes. (P. 130.) His minor premises are thus stated:

There are two facts that are undeniable; which are not only necessary to establish our theory but they render it incontestable. The first fact is that the Earth and the Atmosphere at the equinoxes always undergo an intense electric disturbance; and the second is that the telluric disturbance extends to and affects the sun, [p. 18] and through it the other planets.

It may be true that the earth undergoes an intense electrical excitement at each equinox. It is generally supposed that with the change of seasons which accompanies the passage of the sun from the north of the equator to the south, or the reverse, the weather is much unsettled. The swinging of the periodic winds, the shifting of the zone of calms, and the high atmospheric tides which must result from the sun's being in the plane of the equator, make this seem quite reasonable and in harmony with observation. But the second "undeniable fact," that the "telluric disturbances extend to and affect the sun," will, I fear, be seriously called in question if it is meant that they *sensibly* affect the sun. In proof of this "fact"—and it is the proof he offers—Mr. Tice says that "it is established by observation that sun spots have a marked maximum during our equinoxes." I do not find this to be true. I have carefully examined the elaborate panoramic plates of Mr. Carrington, in which he gives the solar spots observed by himself during the nine years from 1853 to 1862, *and I find no such maxima in the equinoctial months*, nor, indeed, in any other months. Of course, I am sorry to deny an undeniable fact, especially one so essential to Mr. Tice's argument; but I find no evidence whatever for supposing that the equinoctial storms of our earth sensibly affect the sun.

Having proved the influence of the earth's equinoxes, he wishes to show the immense influence of the equinoxes of Jupiter. Hence the adoption of Jupiter's year as the "great cycle" is all important to his demonstration, and as it is really a point of considerable interest I will ask you to examine carefully this table of dates:

| I. Dates of maximum sun-spot frequency. | II. Dates of Jupiter's aphelion. | III. Mr. Tice's major equinoxes of Jupiter. | IV. Mr. Tice's minor equinoxes of Jupiter. |
|---|---|---|---|
| 1816.8 | 1815.20 | 1812.44 | 1818.37 |
| 1829.5 | 1827.16 | 1824.30 | 1830.23 |
| 1837.2 | 1839.12 | 1836.16 | 1842.09 |
| 1846.6 | 1850.98 | 1848.02 | 1853.95 |
| 1860.2 | 1862.94 | 1859.88 | 1865.81 |
| 1871.6 | 1874.80 | 1871.74 | 1877.67 |

Column I gives the dates of maximum sun-spot frequency in which all observers substantially agree. Column II gives the dates of Jupi-

ter's aphelion. Columns III and IV contain the dates of what Mr. Tice calls the " major " and " minor " equinoxes of Jupiter. As to the determination of these dates I shall have something to say further on.

It is easily seen that neither of the last three columns agrees very closely with the first. This is due, as was said above, to the difference between Jupiter's period and the sun-spot period. The dates in the last three columns regularly increase by 11.86 years, while those in the first are irregular, with an average interval of about eleven years. It is incredible that anyone should consider the coincidence of either one of the last three with the first as " demonstrated." Mr. Tice gives, no doubt unintentionally, a false impression in regard to the dates of sun-spot frequency. He heads Column I of this table " Average maxima," and from his remarks one would conclude that each was the *average* of two dates, agreeing respectively more closely with Columns III and IV. Now, in the first place, the dates in the first column are not averages at all; they are the years when sun spots, magnetic storms, and cyclones were actually most numerous.[a]

An examination of Professor Wolf's analysis of Schwabe's observations shows that Mr. Tice should not have used the heading "*Average maxima.*"

Moreover, the dates of minimum sun-spot frequency are very nearly midway between those of maximum. So that, if Mr. Tice's " major equinox " coincides with the time of the maximum his " minor equinox," instead of being coincident with a second maximum, must nearly coincide with the absolute minimum.

Of course we can not enter more fully into these interesting subjects. Many volumes have been written upon them, and they still claim the attention of astronomers and physicists.[b]

Nothing is clearer than that our author has been guilty of a credulity unbecoming a scientific man in assuming it to be *proved* that Jupiter is the main cause of the solar period, and building upon such a very insecure foundation. He says:

> For ourselves, without any hesitation and qualification, we accept it no longer as a theory, but as demonstrated and verified truth that not only the occurrences of Jupiter's equinoxes but those of the other planets are the causes of the disturbances in the sun, and consequently *in the whole solar system.* (P. 75.)

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[a] When Professor Woodward read this lecture in the hall of Washington University he exhibited a graphical representation of the occurrence of sun spots. The curve of frequency ran sharply to a maximum once during every eleven years like irregular teeth in a saw—EDITOR.

[b] In a recent address Professor Huxley discusses the relation of planets to the sun spots, and while he points out some coincidences in the case of the nearer planets he makes no mention of Jupiter. (See Popular Science Monthly for November, 1875.)

It is worthy of remark in connection with this statement of a firm conviction that Jupiter is the cause of the periodic phenomena of sun spots, that the maximum of spots occurs, according to the table we just examined, when Jupiter is near his aphelion, or greatest distance from the sun. Were he the cause of the spots (of which Mr. Tice has not the slightest doubt) we should expect quite the reverse to be true, as it is not consonant with our experience that a physical cause has the greater effect the farther it is away.

We come now to the most remarkable features of Mr. Tice's book, viz, his theory of planetary equinoxes and his methods of determining their dates. His theory is given above, in his own words. Let us examine his demonstration.

But first I must remind you of a little elementary astronomy. The axes of the sun and the planets preserve almost exactly their directions in space in spite of their revolutions about each other. The different axes are by no means parallel, but each points continuously to the same spot on the infinite celestial sphere. In this statement I ignore the effect of precession and nutation observed in the case of every member of the solar system, because the annual changes are so very small. All are familiar with the fact that the plane of the earth's equator, the "equinoctial," lies half the year on one side the sun and half the year on the other as the earth moves around its orbit, and that twice in the year this plane passes through the sun. At such times the sun appears to us to be on the celestial equator, or "on the line," and as the sun is visible from one pole to the other of the earth just twelve hours by day and invisible just twelve hours by night, these two positions of the earth are called its "equinoxes." A similar statement may be made for each planet. Hence each planet passes two equinoxes during each of its years. When on one side of the sun, say north of it, the planet's south pole is specially exposed to solar influence, and when south of the sun the north pole is similarly exposed. The importance of these changes in producing "seasons" obviously depends upon the size of the angle which the plane of the planet's equator makes with the plane of its path.

But there is another inclined plane which is of first importance in stating Mr. Tice's theory. The sun at the center of the system revolves upon its own axis, and although his axis is nearly perpendicular to the planes of the planets' orbits, it is in no case exactly so. The consequence of this obliquity of the solar axis is that each planet is during one-half of the year exposed to one pole of the sun and during the other half to the other. In the case of the earth, we get our greatest view of the south pole of the sun March 6 and our best view of the north pole September 5. On these dates the earth is at its gr[illegible]istances south and north of the plane of the sun's equat[illegible]ll observe the degree of coincidence between these

dates and those of the equinoxes, March 22 and September 21. The difference, however, is not a constant quantity.[a]

Now, Mr. Tice regards the sun and each one of the planets as an immense magnet, such as would be formed by passing a current of electricity through a coil of wire through the center of which, in a line perpendicular to its plane, there is a bar of soft iron. Of course, such a magnet has a north pole and a south pole, depending upon the direction in which the current flows. He assumes in all his reasonings that this current coincides with the equatorial belt and that the magnetic axis coincides with the axis of rotation. To be sure, he refers to the lack of coincidence of these axes in the case of the earth, and suggests that the like may be true of the sun, but elsewhere he assumes their agreement.[b]

It is obvious that two such magnets would in general influence each other, like poles repelling and unlike poles attracting each other, and in the case of moving magnets that the strength of such influence would vary. Our author thus refers to the earth's alternate exposure to the poles of the sun:

> In consequence of the inclination of the earth's axis to the plane of the Ecliptic, the South magnetic pole of the Sun at one Equinox, and his North magnetic pole at the other, are pointed more directly toward the earth than at any other points on its orbit. (P. 15.)

You will remember that I showed you that the earth was at its points of greatest distance north and south of the sun's equator only about sixteen days before the equinoxes. In the last quotation you will notice that it is assumed that these points coincide. Then he assumes that a like coincidence exists in the case of every planet, and thus proceeds to give the source of the influence of such an equinox.

> These existing causes (which not only arouse the planets to greater activity, *but influence the sun himself* to modify, diversify and vary his energy,) are the equinoxes by which a planet alternately renews its electric vigor; now by the North, and anon by the South magnetic pole of the Sun, thus alternately imbibing electric energies that, we have good reason for believing, differ in many essential properties. (P. 95.)

You will be surprised to know that after making the above statements of the source of the special influence of a planetary equinox, he nowhere mentions the amount of this alternate exposure of a planet to

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[a] Mr. Tice gives the difference between these dates as ten days, but he evidently follows Herschel, who does not give the later and more accurate data.

[b] This suggestion is made by Mr. Tice, in these words:

"Since it is probable that the magnetic poles of the Sun, like those of the Earth, do not coincide with the poles of his axial rotation; hence, if this is the case, each solar pole is equivalent to a moving magnet to all the planets, and therefore a powerful generator of electricity in them" (p. 15). He says (p. 16): "All rotating bodies, from a disc to a sphere, generate electric currents at right angles to the axis of rotation."

Behold how easily the man was satisfied of the truth of his theory of the equinoxes even before he went on his fruitless search for the dates of those puissant epochs. We can not help regretting Mr. Tice's limited opportunities for consulting astronomical data, for the dates of the equinoxes of Mars and Saturn are well known, as are probably those of Jupiter. Great uncertainty attends the data respecting Venus, while nothing is known as to the equinoxes of Mercury, Uranus, and Neptune. (The satellites of the last two suggest the positions of the equatorial planes.) As for Vulcan, as he is chiefly the creation of Mr. Tice's own brain, I shall not deny his right to assign him his equinoxes. What, then, does Mr. Tice do? The quotations already made clearly show the assumption that the equinoxes of a planet occur when it is at its greatest distances north and south of the plane of the solar equator. Consistency demands that he should calculate (as is easily done) when the several planets are at these points and call such positions equinoctial points. Does he do this? Not at all. First, he tried to reason it out in this way, and it carries him in an entirely new direction:

> The first thing was to establish the solsticial points, upon which the books are equally as silent as upon the equinoctial, but as *telluric analogy* had served my purposes well so far, I relied upon it to furnish me both the solsticial and equinoctial points. On the Earth's orbit I found the *perihelion* and *aphelion* points closely coincide with the solsticial points. *I hence inferred that this might be the case with Jupiter;* and if so, that the law might be general. (P. 24.)

In spite of his attempt at reasoning, he tells the exact truth on page 23, when he says:

> We have already stated that we assumed the perihelion and aphelion points of Jupiter's orbit to be intermediate between his equinoctial points.

Let us examine these remarkable statements.

"Telluric analogy" teaches him that the solsticial points of a planet coincide with the perihelion and aphelion points, or, in astronomical language, the line of the equinoxes is at right angles to the lines of apsides. Now, this is certainly intelligible, and, if true, very convenient, but unluckily it is not true either of the planets in general at the present time, nor is it true permanently of any planet, not even of the earth. Had Mr. Tice consulted "telluric analogy" a little more faithfully, he woud have found that owing to the advance of the line of apsides and the retreat of the line of equinoxes, the coincidences between the perihelion and the winter solstice which now exists within eleven days will, in the space of about 5,760 years, become an *exact coincidence between perihelion and the vernal equinox*, and that some 7,000 years ago *perihelion coincided with the autumnal equinox.* Analogy should have taught our author that

there is and can be no fixed relations between these points in any case.[a]

Thus far is Mr. Tice furnished with two simple and expeditious, but totally different, methods of " determining " the equinoxes of a planet—

First. They are the points in its orbit farthest removed from the plane of the sun's equator; and

Second. They are the points midway between the perihelion and aphelion points.

But he is not content. A third method, as unlike either of the other two as each is from the truth, is suggested by " telluric analogy."

By following the suggestion that they (Jupiter's solstices) would be found where the plane of his orbit is highest above, or deepest below the plane of the ecliptic, it was inferred that the Jovian tropics and consequent solstices, might be approximately ascertained. Inquiry was instituted in that direction, and it was ascertained that the Tropics or solstices of Jupiter were at the points inferred, and that they exactly coincided with his perihelion and aphelion; and hence of course his equinoxes must be ninety degrees from either of these points. (P. 24.)

I am almost willing to believe that Mr. Tice never wrote these words, and that they were interpolated by a depraved printer, so profound an ignorance of geometry and astronomy do they betray. I should acquit Mr. Tice of all responsibility in the matter did I not find later another sentence in the same vein.

Thus (p. 26):

In Jupiter the perihelion and aphelion points on his orbit, and his solsticial points exactly coincide, *judging by the plane of the Ecliptic.*

If this third method means anything, it means that a planet's equinoxes occur at its nodes—i. e., those points on its path where it passes through the ecliptic. His analogy seems to be a little weak, as the earth obstinately refuses to go either " above " or " below " the plane of the ecliptic, and that is the reason, perhaps, that we do not hear of this method again. Of course, these three methods of " determining " the equinoxes of the planets would give very different sets of dates, and there is not the slightest probability that any one of them would chance to be true. The statement quoted above, for instance,

[a] In cosmographical questions a thousand years are as a day. Mr. Tice says (p. 129): " We offer planetary equinoxes for a fundamental principle of meteorology, which are permanently fixed astronomical events that have occurred at their allotted periods as long as the solar system has existed, and will occur as long as it endures." Again, he speaks of calculating when Jupiter "was at either equinox in all time that is past " and "when he will be at all time that is to come." Throughout, Mr. Tice ignores the astronomical fact that no planet has fixed equinoctial points, or, in other words, that in no case is the siderial year the same as the equinoctial year, and that neither of these agrees with the anomalistic year.

that the perihelion and aphelion points of Jupiter's orbit "exactly coincide" with the points of the greatest distance north or south of the ecliptic is false, at the present date, to the amount of nearly two months, and this interval is a quantity varying all the way from nothing to about three years.[a]

As to which of his three methods Mr. Tice does actually use in forming the tables of planetary equinoxes on which his predictions are based, I am not wholly certain. It is clear that in the case of Jupiter he takes the second. In the case of Saturn he discards all three methods and gives very closely the true dates of his equinoxes, thus showing that, in spite of his assertions to the contrary, he found them set down in the books. The date of Saturn's nearest equinox would be, according to Mr. Tice's first method, June 12, 1878; second method, November 11, 1878; third method, December 2, 1872. Mr. Tice gives November 12, 1877. The true date is September 28, 1877.

As to Venus, Mars, and Mercury a brief examination of the table in his appendix convinced me that he had followed neither method carefully.

I admit that it seems incredible that anyone should have mixed up three arbitrary methods of determining the exquinoxes of a planet, as according to my showing Mr. Tice has done. Should anyone doubt the fairness of my report, I beg of him to read our author for himself, but I warn him to take with him a stock of infinite patience, and not to expect to understand the book till he has read it almost literally forward and backward. In extenuation of Mr. Tice's logic I ought to say that I do not think he was conscious of any inconsistency. He was wholly under the spell of his "telluric analogy." The approximate coincidence at the present epoch of the earth's perihelion (January 1), its winter solstice (December 21), and its passing through the sun's equator (December 6) led him to infer that they were equally coincident in the case of the other planets. It would have been very easy for him to see that this was not true in the case of Saturn and only temporarily true of the earth, but he seems to have thought the coincidence incontestably proved by his record of storms. It is fortunate for Mr. Tice that he does not claim absolute accuracy for his equinoctial dates.

All that I claim is that, they are approximations *arrived at from general principles, the only data at my command.* My purpose is to prove that planetary equinoxes affect, and I might say, determine the meteorological phenomena of our Globe. *I could not succeed in my purpose unless I knew, at least approximately,* the points on the orbits of the several planets where the equinoxes occur. (P. 26.)

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[a] Jupiter was at his greatest distance north of the ecliptic August 29, 1874. He was in aphelion October 24, 1874. Mr. Tice must have "instituted" his inquiry in the direction of a very poor almanac.

If his success is only proportioned to the soundness of his deductions from general principles, there is hardly ground for offering him our congratulations.

Here I must leave Mr. Tice's theory of planetary equinoxes, nor do I propose to discuss his meteorological records, nor say much of his tables of dates. It is certain that the latter have no astronomical value and that by his method of verifying dates one set is as capable of " incontestable proof " as another. As to Mr. Tice's planet Vulcan, on which he relies so largely, I have few words to say. I intimated a moment ago that it was chiefly a creature of Mr. Tice's own brain. Let us see if it is not so.

According to his account, having ascertained that the Saturnian and Jovian equinoxes produce sun spots, earth currents, earthquakes, etc., that the equinoxes of the earth, besides intensifying the effect of the larger planets, were especially fruitful in tropical cyclones, it seems probable to him that all atmospheric phenomena were produced by planetary equinoxes. "Acting on this suggestion " he watched the effect of the equinoxial points of Venus, determined as I have already shown. " The result was astounding, fully verifying the suggestion." " Similar satisfactory and astounding results " attended an observation of the equinoxes of Mercury. But the catalogue of phenomena was not yet exhausted.

It was soon discovered that not only many phenomena occurred to which it was impossible to assign a place in any of the known cycles, but which under certain conditions, were *so terrifically energetic that they must have a sufficient though unknown cause.*

I dare not venture an opinion as to the meaning of this last clause. He classed all such unaccounted-for phenomena as " unknown." The unknown class consisted chiefly of cyclones, but there were many auroras, some earthquakes, and sun spots. He noted that these phenomena occurred about every twenty-three days. " The suggestion that they might be referable to Vulcan, the gigantic planet nearest the Sun, soon became a firm conviction." Elsewhere (p. 170) he says:

Other extraordinary phenomena were so far removed from any other known cause, that unless they are due to Vulcan's equinoxes *no other cause can be assigned for them.*

It is obvious, then, that the existence of Vulcan is absolutely necessary to the theory of planetary equinoxes, and the " demonstration " and " verification " of the truth of his " conjecture," that his period of revolution about the sun is forty-six days, is so strong that I almost believe he would have manufactured a new planet out of hand had the suggestion of Vulcan not been already made. To be sure, Mr. Tice says, in an ungarded moment and quite out of keeping

with the rest of the book, that his theory may be vulnerable just at this point of Vulcan. This is in the face of the statement that there is no reasonable doubt of the existence of Vulcan, and in spite, too, of his demonstration of the length of his period.

Now, as to the existence of a planet interior to Mercury, astronomers have not been agreed. At one time some had no doubt that one had been seen; at present, however, most astronomers deny that we have any valid ground for believing in the existence of such a planet.

M. Lescarbault, a French physician, and Mr. Lummis, a business man of Manchester, England, and Mr. Tice claim to have seen an interior planet the 1st of March, 1859, and Mr. Lummis, in March, 1862. Neither of these men was an educated astronomer, and neither had an instrument of much power or accuracy. From the rough data furnished by M. Lescarbault, Le Verrier computed the elements of its orbit, making its period nineteen days seventeen hours. From the data furnished by Mr. Lummis two French astronomers computed the elements, one making its period nineteen days twenty-two hours and the other seventeen days thirteen hours. The world knew nothing about Mr. Tice's observation till the publication of his Elements of Meteorology a few months ago.

As to the observation of M. Lescarbault, it ought to be said that at the same hour M. Lais, a French astronomer in Brazil, was examining the surface of the sun, and he—

> is positively certain that nothing of the kind was visible, though the telescope that he employed was considerably more powerful than that of the French physician. (Chambers's Astronomy, p. 50.)

Mr. Tice knew nothing of the observation of Mr. Lummis and the close agreement of the computed periods. He says that as far as his information goes "Vulcan has been seen but twice—once by its discoverer, M. Lescarbault, March 26, 1859," and by himself September 25 or 26 the same year. No one can fail to be struck with the account Mr. Tice gives of his own observation. He says he had the good fortune of seeing Vulcan make a transit a few days after the autumnal equinox in 1859. A few weeks later it occurred to him that it was not Mercury, as at first supposed.

> I then made a record as near as I could of the date, and *its apparent size I recorded as two and one-fourth inches in diameter. As this would give it an enormous size*, I have since got those who also saw it to give me their impression as to its size. I find they vary from mine *a quarter of an inch*, some placing it that much more and others that much less. Probably all these apparent sizes are too great, but they nevertheless clearly establish one thing that the planet is of gigantic dimensions.

You need not be told that such a record as this is totally unscientific and perfectly unintelligible. Apparent size is measured by the visual angle an object subtends and is given in degrees, minutes, and

seconds. It is as dependent on the distance as upon actual size. As far as this record goes, the object seen may have been no larger than a football, or it may have equaled the sun. Mr. Tice elsewhere tells us that Vulcan is fully equal to if not much greater than Venus. If now he will be good enough to tell us how he finds that an apparent diameter of 2¼ inches indicates the size of Venus, we will with equal exactness compute Vulcan's distance from us and from the sun, and, by Kepler's third law, its period of revolution. Mr. Tice is singularly unfortunate in the period which he adopts for Vulcan. You will remember that its discovery dates from March 26, 1859, when the Frenchman saw a dark object passing between the earth and the sun, and that Mr. Tice saw it on September 26 the same year. Now, the interval between these two observations was one hundred and eighty-four days. Mr. Tice's Vulcanian period of forty-six days is contained in this exactly four times, so that between the observations Vulcan made four complete revolutions. One can hardly fail to suppose that Mr. Tice was the more willing to adopt forty-six days as his cycle, seeing that it "comes out even." But it is easily seen that either this period is fatal to his observation or his observation is fatal to this period, for during these one hundred and eighty-four days, or six months, the earth had traveled almost exactly one-half of its orbit and Vulcan had made four complete revolutions, his period or year being forty-six days, so that on September 26 Mr. Tice must have been on one side of the sun and Vulcan exactly opposite, as far as possible from a transit. This is a point which Mr. Tice must have innocently overlooked and which it is impossible to explain away or ignore. What Mr. Tice really saw remains to be told.

Mars could be sacrificed with little inconvenience to Mr. Tice's theory; even Mercury could be spared without serious injury; but Vulcan must be preserved at all cost. Vulcan is the very prop that doth sustain the house. His size, his period, and the dates of his equinoxes are all essential to the theory, and yet I have shown you that you must abandon the size of Vulcan (for that depends solely upon Mr. Tice's observation) or you must give up the period of forty-six days. You can take your choice.

There is another fatal objection to Mr. Tice's Vulcan. A period of forty-six days would involve a mean distance from the sun of about 24,000,000 miles; and as Mercury's mean radius is only about 36,000,000, their distance apart when in conjunction would be only about 12,000,000 miles. Now, the least distance between Venus and Mercury is over 30,000,000 miles, so that the strength of Vulcan's attraction for Mercury would be fully six times as great as that of Venus. Le Verrier accounted for the perturbations of Mercury by supposing the mass of Venus to be increased one-tenth. The perturbing force of Mr. Tice's Vulcan would be at least sixty times too great.

Since the suggestion of Vulcan was first made not an eclipse of the sun has been allowed to pass without the appointment of an astronomer in every party of observers whose sole duty has been to search for inter-Mercurial planets while the intense light of the sun should for a moment be darkened. In addition to this the face of the sun has been under almost constant inspection by trained observers at different stations round the earth, each ready to note the transit of a planet, and yet nothing more has been seen of Vulcan during all these sixteen years. The probability that a planet as large as Venus, and as near Mercury as Mr. Tice imagines Vulcan to be, should thus baffle our observers is very small indeed.

Some confusion exists as to the energy of Vulcan's influence at his equinoxes, though I infer that it is immense when immense energy is exhibited and not noticeable when none is noticed; in fact, it depends upon the weather. This cautious inference is based on such remarks as these:

"Vulcan, gigantic in size and fearfully strong in position, with physical laws operating such as our theory postulates, must at his equinoxes produce just such phenomena as the world has witnessed within the last three weeks" (p. 137)—that is, in July last. Vulcan, you will remember, has an equinox every twenty-three days, so that if he "must produce" each time twenty-one days of heavy rain, we shall have forty-two days of rain, or a new deluge, every Vulcanian year.

Again, we find that Vulcan "carved out nine-tenths of the most violent and terrific phenomena of the Jovial, Telluric, and Venusian classes."

On page 137 he says:

> Vulcan's size and position near the sun give him terrific energy, which *he never fails to display at his allotted times.*

And so on with many repetitions.

On the other hand, he says:

> A Vulcanian equinox *ordinarily passes without causing phenomena so remarkable as to attract attention.* (P. 29.)

I will close my remarks upon this branch of the subject by calling your attention to a most remarkable period during which not only Vulcan but nearly all the other planets are shorn of their strength and prowess. On page 50 he says: "There was a period of comparative repose from 1819 to 1829," and this was in spite of a "major equinox" of Jupiter, about 10 equinoxes of Mars, 20 of the earth, 32 of Venus, 40 or 50 of Mercury, and 160 of Vulcan.

I am well aware that even if it has been clearly shown that Mr. Tice's explanations of the influence of a planetary equinox are either weak or altogether false, it will be claimed that such influence may

still exist. It is hard to prove a negative, and as no one can deny that even the remotest planet has some influence upon all things terrestrial, an equinoctial disturbance might possibly affect us, just as the falling of an aerolite in China increases the mass of the whole earth, and hence increases the strength of its attraction upon every object on its surface, and this increases the liability of every structure to fall to the ground. This increase is, of course, infinitesimal, but it exists. So with the influence of any planet at any point in its orbit. It is infinitely less than that of the moon even, which was formerly considered the great weather breeder, but which has lately been discarded as wholly insufficient.

I have shown that Mr. Tice's methods of determining the dates of the several equinoxes are confused, contradictory, and incorrect, and yet I can not *prove* that those of Mercury and Venus may not be correct, though the chances are at least a thousand to one against them. Those of Mars, if they were deduced from his perihelion (as I suppose they were), are in error about thirty-four days. Again, although it is not at all probable that any such planet as Mr. Tice's Vulcan exists, he may exist. If he exists, it is highly probable that his orbit lies closely to the plane of the sun's equator, so that Mr. Tice's magnetic theory fails. If he does exist, all the evidences we have fixes his orbital period or year at about nineteen and one-half days instead of forty-six. Now, finally, if Vulcan exists, and his orbit is inclined to the solar equator and his period is forty-six days and he is about the size of Venus, the chances are still twenty-three to one that Mr. Tice has not correctly assumed the dates of his equinoxes, so that the chances on the whole against his all powerful and strictly essential Vulcanian equinoxes are *millions* to *one*. Still, I suppose, we must allow Mr. Tice's enthusiastic followers (and the columns of our newspapers and journals show that he has a fair following) to take that one chance and cling to it so long as they can see truth in his predictions.

I am quite unwilling to make any examination of his meteorological records. Our knowledge of the weather yesterday, last week, or last year is merely local and very imperfect indeed. I have no idea that a day ever passes without great changes in temperature and in atmospheric pressure, without rain or snow, without driving storm or whirlwind, somewhere on the face of the earth. Mr. Tice predicts, for instance, that there will be a heavy storm to-morrow. Do you doubt you will find one if you will only look far enough? Of course, you can prove any prediction of storm if you will only consult a weather bureau in every land and on every sea. And in examining the past, with a terrible equinox every twenty-three days of from seven to eleven days' duration, and five other equinoxes, *each covering half the calendar* (for the duration of each equinox is one-fourth the

planet's period of revolution about the sun), it is certainly easy to account for everything. The only difficult thing to explain is the occasional interval of repose which, in spite of all the planets, we do enjoy. The electrical excitement of the whole earth resulting from the influence of any of the heavenly bodies must be general in its manifestation and not local, so that local storms, from purely astronomical causes, would seem to be impossible. Mr. Tice has spread out each equinox from the necessity he was under of embracing all the phenomena, until pretty nearly every day in every year is covered up, often several times; and were his predictions consistent nearly every day would be consigned to storms.

For example, according to his table the entire year 1875 is under the shadow of a Saturnian equinox; hence one of Farmer Thomas's distributed predictions is always in order: "High wind—and rain—may be expected—about this time." The six months—February, March, April and August, September and October—are embraced by the equinoxes of the earth. From the middle of February to the middle of last July the equinox of Mars raged. Venus adds her influence this year during February and March, June and July, and from the middle of September to the middle of November. Mercury and Vulcan each cover about half of each month throughout the year. The month of October is especially doomed. The combined influence of Saturn, Venus, the earth, Mercury, and Vulcan is expected to produce terriffic results. I have no doubt the prediction will be fully realized. If the valley of the Mississippi chances to escape terrible earthquakes, tornadoes, and floods, it will certainly be found that there was a low barometer in Brazil, or a whirlwind in New Zealand, or an earthquake in Iceland.[a]

Still, on the other hand, there are occasional openings even in Mr. Tice's table where a little quiet freedom from phenomena may be enjoyed. Let us examine January, 1874. That was, according to Mr. Tice, a white month. Jupiter and Saturn, those mighty disturbers of the peace, were quiet. Venus was, after the 6th, reserving her charms for the spring months. The term of service of the warlike Mars did not begin last year till about the 1st of March. Mercury was off duty till the 28th of the month. That terrible blacksmith, Vulcan, with his sledge-hammer blows, was resting idle from the 10th to the 22d of the month, and the weary earth was still dreamlessly sleeping in the arms of her winter solstice. For once all disturbing forces were stilled and throughout the whole solar system peace and tranquillity reigned supreme for the space of twelve days.

[a] Since the first reading of this paper October has passed. For a Ticean account of the way in which the prediction was verified the reader is referred to the St. Louis Times, October 29.

Nothing ever happens without a cause, and nothing could happen then, *for there was no cause.* Picture to yourself that blissful period. No rain, no snow; no tearing gale, no ominous calm; no low, no high barometer; no low no high thermometer, for all these are phenomena which prove the influence of a planetary equinox.

Dare the faithful believers in Mr. Tice's equinoxes consult the record of those twelve days, knowing that any physical disturbance would be absolutely fatal to the theory? The sequence of cause and effect is invariable and necessary, and if meteorological phenomena occurred then they were, according to Mr. Tice, without astronomical cause, and hence may occur again without astronomical cause, and the whole equinoctial fabric falls to the ground. I am not going to tell you all that did happen on those few days, for I do not know; but I do not suppose, nor does any one of you suppose, that the face of the earth was absolutely devoid of phenomena during that period. Remember there must be (if you wish to save the theory) no positive changes of any kind other than those invariably connected with day and night. It is not at all a question of degree; it is a question of something or nothing.

Now, Mr. Tice quotes from the Weather Review of January, 1874, low barometer No. I on the 3d, 4th, and 5th, and low barometer No. II on the 6th and 7th, as proving the influence of the Vulcanian equinox of the 4th. Again, he quotes the low barometer No. VII of that month, which took place on the 27th and 28th, as indicating the influence of another Vulcanian equinox on the 27th, and seems well satisfied with the verification. But what of the four low barometers, Nos. III, IV, V, and VI, occurring during the middle of the month, each one of which was a storm center traveling across our land?

All these storms actually took place during this quiescent interval in spite of the obvious impropriety of their doing so and in spite of the deadly injury they inflicted upon this wonderful theory.

I have examined the Weather Review for that month, and I find that storm No. IV originated in the Mississippi Valley and was first marked as central in Missouri on the morning of the 13th. It moved to the eastward with a mean velocity of 50 miles per hour, causing very high winds on the eastern coast.

During the 15th and 16th of the month a severe storm prevailed on the Pacific coast, extending from central California to the west coast of British America, and the barometer fell to the unusual reading of 29.06 inches at Portland, Oreg. At Fort Garry the barometer stood at 29 inches, the lowest reading during the month.

In examining the Weather Report of this month Mr. Tice found the storms which showed the effect of Vulcan's equinoxes because he was looking for them, but failed to note the greatest phenomenon of

# DISCUSSION OF LONG-RANGE WEATHER FORECASTS.

By Professor E. B. GARRIOTT.

## INTRODUCTION.

Historical references indicate that at an early period in the history of the world man began to associate certain kinds of weather with certain appearances of the heavenly bodies, and that with advances in human knowledge meteorology and astronomy became associated branches of science that embraced all appearances of the sky and the visible phenomena of the atmosphere. In Babylonia rotations of the weather were defined by meteorological and astronomical observations, and in Egypt, where material prosperity has ever rested on the annual rise and fall of the Nile, the periodic appearance of certain constellations revealed the recurring seasons of drought and flood. The Romans and the Greeks were close observers of the weather, and it is a matter of record that during several centuries before Christ they collected and systematized records and traditions regarding the various phenomena of the atmosphere.

Meteorology was not wholly disassociated from astronomy until Copernicus solved the problem of the solar system. The fact was then made clear that the general character of the seasons was controlled by practically immutable astronomical causes, and that the weather forecasts of the ancients were merely statements of climatic or general weather conditions that by observation had been associated with the heavenly constellations. In other words, the system of weather forecasting that had for a basis a calculation of supposed stellar influences was effectually discredited when the sun and the movements of the earth around the sun, and not the stars, were found to be responsible for the weather that is peculiar to the several seasons. An explanation of the apparent success of the system is found in the sharply marked character of seasonal weather in southern Asia and the countries bordering on the Mediterranean Sea, and an additional cause for abandoning the system is found in the fact that as centers of civilization shifted to more northern latitudes the weather of the various seasons exhibited greater irregularities and variations.

In the seventeenth century, the invention of the thermometer, credited to Galileo, and later the invention of the barometer, by Torricelli,



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afforded means for accurately determining the temperature and weight, or pressure, of the earth's atmosphere, and observations obtained by the use of these instruments facilitated a definition of climatic features and permitted more accurate interpretations of the meaning of local weather signs. During the seventeenth and eighteenth centuries long-range weather forecasting, with other practices of an astrological nature, gradually disappeared from the field of legitimate science. During this period, however, men of recognized scientific attainments were actively engaged in investigations regarding the composition, physical properties, and phenomena of the earth's atmosphere, and climatical problems were systematically considered. Instrumental observations, and especially those furnished by the barometer, aided materially in determining the character of impending weather changes, and barometric indications of the approach and passage of storms were of great value to navigators.

Previous to the nineteenth century man possessed no knowledge of the laws that govern the weather, nor of the mechanical processes that are employed in the production and propagation of storms and other well-marked phenomena of the atmosphere. He had noted, without knowing the reason therefor, that in the Northern Hemisphere northerly winds are usually attended by low temperature and southerly winds by rising temperature; that in the middle latitudes easterly winds are generally followed by rain or snow and westerly winds by clearing or fair weather; that certain cloud formations and movements indicate certain kinds of weather, and that manifestations of atmospheric moisture are of value in determining the character of impending weather changes. He had learned by observation to interpret the meaning of effects produced by certain atmospheric conditions on objects animate and inanimate, and had acquired an intimate knowledge of astronomical events that govern the seasons. About the middle of the eighteenth century Benjamin Franklin, who first conceived the idea that electricity and lightning are identical, discovered that the northeast storms of the Atlantic coast of the United States actually advance from the south or southwest and are first experienced on the southern coasts.

A formal announcement of the law of storms was made by William C. Redfield, of New York, in 1821. Redfield's deductions were based upon observations taken along the Atlantic coast of the United States. He found that the whole of the revolving mass of air that composes the storms of that region advances with a progressive motion from southwest to northeast. In later years he drew conclusions regarding storms in general that have not been materially modified by subsequent research.

The history of meteorological progress during the last half of the nineteenth century is embodied in many reports and publications, ref-

erence to which will be made in connection with the subject under discussion. The sum of the achievements of this period in practical and theoretical work and investigation is represented by a rapidly increasing collection of data and facts that afford a sure foundation upon which future work may rest.

The United States Weather Bureau, which possesses facilities that permit it to surpass all other meteorological services in the accuracy of its predictions, now issues forecasts each day for periods of one and two days in advance, and at times the period is extended to three or four days. This is the greatest length of time for which calculations based upon present available data and information can be made. The data referred to is received daily by telegraph from an area that embraces the United States, Canada, the western Atlantic Ocean, the West Indies, and Mexico, and the forecasts are results of careful studies from day to day of atmospheric changes, movements, and developments that appear within the region of observation. The daily calculations thus prepared are subjected to a rigid verification that yields 80 to 85 per cent of verified forecasts that have been made in detail for each twelve hours of the forecast period. In the case of forecasts of severe storms, well-marked cold waves, frosts, and other phases of the weather that are calculated to cause serious loss or inconvenience to commercial and industrial interests, and also in the forecasting of floods in the principal rivers of the country, the forecasts are almost invariably timely and accurate. While the predictions thus issued are not long-range forecasts, it is interesting to note that the period for which forecasts have been officially and regularly made has been extended during the last thirty-three years from eight hours to forty-eight hours without a lowering of percentage of verification.

A further extension of the forecast period depends in a measure on an enlargement of the area covered by telegraphic reports of simultaneous observations. In weather calculations based on recognized physical laws time limitations must be fixed by the period of transition over the region of observation of well-defined storms. If the region has a longitudinal width of 3,000 miles and the average eastward progress of storms is 700 miles a day, the time that will elapse from the first to the last appearance of an average storm within the region of observation will be between four and five days. Allowing the storm one day to enter the region after the first indications of its approach are observed on the western border, and another day for its setting in ahead of the actual center of disturbance, there remains less than three days for forecasts of its advance to the easternmost parts of the region. Assuming that the storm follows the time and route schedule made on its first appearance, it is reasonable to expect that its passage will be followed by two or three days of fine weather, and

predictions based on this assumption, while not strictly legitimate, are nevertheless statements of conditions that are natural sequences to the conditions forecast and depend for their verification upon a justification of the original forecast. It appears, therefore, that with present facilities the forecast period can at times be extended to five or six days. In view of this statement, and with a due consideration of the necessarily slow advances that are usually made in the arts and sciences, the progress of weather forecasting during the last third of a century has been remarkable, and another quarter of a century will undoubtedly show a corresponding advance. In the meantime data, knowledge, experience, and honest, well-directed effort will be persistently applied to the problem of practical meteorology in the belief that the particular laws of nature that may control rotations of the weather will be determined.

### THE BASIS OF LONG-RANGE FORECASTS.

"Planetary meteorology" is the term applied to the practice of the more prominent long-range forecasters, and planetary meteorology is one of the relics of astrology; fortune telling is another. When advances in astronomical knowledge made clear to the world at large that the fixed stars do not exercise an influence upon the weather, exponents of the weather branch of the ancient art of astrology with one accord placed upon the moon and several of the planets of the solar system the responsibility of regular and irregular forms of weather. To the moon, however, was given the burden of the responsibility, for be it known that centuries before the Christian era the periods of the new and full moon were associated with current weather, and rotations of certain weather types were supposed to attend a nineteen-year lunar cycle, during which the new and the full moons are repeated on corresponding days of the month.

Some of the most financially successful long-range forecasters of the present time base their forecasts on the moon's path with reference to the ecliptic and the earth's equator, and strengthen their statements by allusions to mysterious Vulcan, eclipses, occultations, and quotations from the Scriptures. Others employ the nineteen-year moon cycle and fall back upon a fund of mysteriously acquired superhuman wisdom and, incidentally, upon past records of the weather; and the manipulation of past records, which have a positive value in climatic work, represents their stock in trade. Other prophets appear from time to time and, lacking in "business" faculty, quickly disappear.

A careful consideration of the merits of the moon as a controller of the weather presents a number of reasons why the claims of fair Cynthia's disciples should be given respectful consideration. The belief is entirely plausible that the earth's nearest neighbor should assume

a part in the management of her affairs. The moon's aspect is changing every day, and so is the weather. The phases of the moon change once a week, and we have a storm about once a week. The storms may be either "regular" or "reactionary;" that is, we may get them coming or going, either before or after the change in the moon. Then there is a certain sentimental feeling for the moon that is due to an inherent regard in the human breast for the mystical and the mysterious. And, finally, the formidable interrogation is launched against unbelievers: The moon influences the tides of the oceans, why should it not influence the weather?

With the burden of proof thus placed upon the scientist, who demands corroborating facts before he can accept in all faith unsupported assumptions of superior wisdom, the long-range weather forecaster continues to exercise, for a consideration drawn from the gentle public, the time-honored practice of playing upon the fancy of the credulous.

### OPINIONS REGARDING THE INFLUENCE OF THE MOON ON THE WEATHER.

The principal object of this paper is to present a summary of the quoted opinions of prominent meteorologists who have endeavored to justify the practice of long-range weather forecasts by facts or theoretical deductions based on known physical laws. A consensus of the opinion of meteorologists appears to be that while the moon undoubtedly exerts a certain influence on the earth's atmosphere the influences are not directly and noticeably contributary to marked normal or abnormal weather conditions.

In a letter delivered by Prof. Dr. J. M. Pernter to the Association for the advancement of Scientific Knowledge, Vienna, January 14, 1903, the following remarks were made regarding the moon as a weather forecasting medium:

> The moon is credited with being the principal dominator of the changes of the weather. The weather is supposed to change by preference with the moon; therefore the new moon and the full moon especially possess the power of influencing the weather, and one of the most widely spread weather rules is that the weather changes with the new moon and with the full moon. However, by many others the first and last quarters are considered of greatest importance. Especially clever observers of the influence of the moon upon the weather pretend to have also observed the distinctive individual influences of the phases known as octants. In general the opinion is very widespread that the decreasing moon exercises a weak and the increasing moon a strong influence. Thus far the theory of the influence of the moon on the weather is the direct result of the popular belief in the moon, without regard to any scientific basis.

Rev. F. L. Odenbach, director of the meteorological observatory, St. Ignatius College, Cleveland, Ohio, has written as follows (Monthly Weather Review, June, 1903):

> With reference to the rain theory of Mr. H. C. Russell, of Sydney, New South Wales, I have looked up the extensive literature on the subject extending through

the two last centuries up to date. An immense amount has been written on the subject.

The sum and substance of all the work done along this line has failed to bring out anything that might be considered a law or be used as a safe rule in questions of climatology or weather forecasting.

I myself think that the moon (and why not the sun and the planets?) *must* have some influence on our weather. Yet this influence must be so slight or so concealed that all these years of observation and hard work have not resulted in anything worth considering.

The great objection I have to this new exposition of Mr. Russell is that from the start he distinguishes between the rainfall on the coast and that of the interior. Why? In this point Mr. Russell follows all of his predecessors. The rule is bolstered up with exceptions and conditions, subconditions, and special combinations until the application becomes a mere guesswork. My general impression on the subject is that about as much time has been wasted on this matter as on the "Perpetuum mobile" and with about the same success. Being in this mood I think it best not to write anything for the Review for fear lest some might take up the matter and neglect other lines of much more importance and far greater utility.

The rain theory of Mr. H. C. Russell, referred to, is discussed as follows by Prof. Cleveland Abbe in the Monthly Weather Review for November, 1902:

Mr. H. C. Russell, director of the observatory at Sydney, New South Wales, has published in the Journal and Proceedings of the Royal Society of New South Wales, for the year 1901, a memoir on the relation of the moon's motion in declination and the quantity of rain in that colony, in which the author concludes "that rain is clearly shown to come in abundance when the moon is in certain degrees of her motion south; but when the moon begins to go north then droughty conditions prevail for seven or even eight years. This phenomenon repeated for three periods of nineteen years each constitutes a marvelous coincidence such that there must be a law connecting the two phenomena.

The influence of the moon on the weather is a matter that will not be downed by the exercise of any amount of common sense. According to the most ancient notions, the moon ought to have and must have a controlling influence in excess of the sun's, and everyone who seeks to demonstrate its power is liable to become infatuated with the study. The moon has so many variations north and south of the equator, north and south of the ecliptic, to and from the earth, from new moon to full moon, conspiring with the sun and opposing the sun, that it does seem as though one ought to be able to make its periodical oscillations agree with some of the many variations in the aspect of the weather. However, we know of but one relation between the moon and the earth's atmosphere that can be said to have been settled upon a rational basis, and that is the matter of atmospheric tides. Laplace stated that the semidiurnal lunar tide in the atmosphere ought to amount to about 0.003 inch of barometric pressure for equatorial stations, and this agrees with the results of observations carried on at Batavia, Java. His formulæ also showed, although we believe he did not state the fact, that as the moon moves north and south of the equator monthly, there ought to be a fortnightly tide, or a general pull of the atmosphere southward for two weeks and northward for two weeks. This we believe was first demonstrated as an observable quantity by A. Poincaré, a civil engineer of Paris, and a member of the Meteorological Society of France. From his articles published by that society in 1885–1888 we learn that the average barometric pressure on parallels of latitude around the whole globe,

as measured by the international maps published by the United States Weather Bureau, gives the folowing results: The pressure on latitude 40° minus that on latitude 10° is +1.88 millimeters when the moon is in the extreme south and +4.82 millimeters when the moon is in the extreme north. The normal difference is +3.35. This indicates that when the moon is farther north there is a slight accumulation of atmosphere in the Northern Hemisphere amounting to 1.47 millimeters, or 0.06 inch of pressure on the parallel of 40°.

Now, all lunar phenomena go through rather rapid periodic changes. What happens in one part of the lunar month is offset by an opposite effect in the other half of the month, or what happens when the sun and moon conspire is offset by an opposite effect a few months or years later, when the sun and moon oppose each other. When the moon is far south and begins to go north, according to Mr. Russell, droughty conditions prevail and continue for seven or eight years. But the strange part is that the moon begins to go north from her extreme southern position every month without exception, not only just before the seven or eight year drought, but during the whole of that long period, and continues to do so during the whole of the succeeding rainy period. How can her beginning to go north be rationally supposed to be a basis for predicting droughts in one case and rains in another?

But if we lay aside these vagaries about the moon and recognize Mr. Russell's meteorological induction that droughty conditions do prevail for seven or eight years in Australia, followed by years of rain, and that this cycle of droughts and rains has been repeated about three times since 1840, then we have a fair observational basis upon which to build a rational explanation. Now, this periodicity, or rather the irregular succession of good seasons and bad seasons, is a fact recognized in every portion of the world. We also have enough data to show that in most cases a drought in one portion of the globe is accompanied by rains in other portions, and that the regions of excess and deficiency of rain move over the surface of the globe month by month and year by year. They do not move in courses so nearly parallel as to justify long-range predictions any more than do our storm centers, but the movements are certainly governed by laws, and we can begin to generalize as a first step in the process from induction to deduction.

For instance, floods in the upper Nile, due to rains in the highlands of central Africa, mean that an unusual proportion of moisture has been taken from the southeast trade-wind current, and that, therefore, when that has been turned northeastward over the Indian Ocean and has become the southwest monsoon of India, it will bring droughts over the western portion of that country. A drought in New South Wales or on the southeast side of Australia means a deficiency in the eastern winds blowing on that coast, and especially so in the rainy season, or December, January, February, and March. But this means that the great area of high pressure over the Indian Ocean at latitude 30° south has been pushed farther west than usual, or, in other words, that the general circulation of the atmosphere in that region has been disturbed. Now, such a disturbance, continuing over several months or even years, can hardly be produced by the rapidly changing moon; it might be due to secular changes in the quantity and quality of the solar heat, but is most of all likely to be simply the result of accumulations of pressure, temperature, and moisture in various portions of the earth's atmosphere. Australia has about the same area as the United States, but lies on the average about 15° nearer the equator. This latter feature gives it soil temperatures and monsoon influences similar to those that prevail in northern Africa, so that it may itself produce an appreciable disturbance of the general circulation in the southern half of our atmosphere. But the principal cause of the droughts in Australia and India is undoubtedly to be

found in the changes going on periodically in the relation between the general atmospheric pressure and resultant circulation in the south and in the north, or between Cape Colony and Australia, China, and eastern Siberia. In this large portion of the globe a system of circulation prevails that is affected but comparatively little by what goes on to the west of it and to the north of it. A large quantity of air enters into this region from the Antarctic Ocean and passes out of it as the southwest monsoon of southern Asia to eventually become the westerly winds of the North Pacific. We may, therefore, look for some connection by this roundabout way between the droughts and rains of Australia or southeastern Asia and those of northwestern America.

It may be interesting at this point to quote two brief utterances regarding the effect on the weather of lunar influences that reflect the attitude of the scientific world toward this matter in 1868 and thirty-five years later. The first was made by Alexander Buchan, M. A., secretary of the Scottish Meteorological Society, and was, in part, as follows:

It is an opinion that has been long and popularly entertained that the changes of the moon have so great an influence on the weather that they may be employed with considerable confidence in prediction. That the moon's changes exercise an influence so strongly marked as to make itself almost immediately felt in bringing about fair or rainy or settled or stormy weather, an examination of meteorological records, extending over many years, conclusively disproves.

The following remarks by Prof. Alfred Angot, of the Central Meteorological Bureau, in Paris, that appear in the Monthly Weather Review for July, 1901, will conclude the presentation of direct testimony concerning lunar influences on meteorology In a final summary of the general subject of long-range forecasts, however, further comment will appear regarding the alleged domination by the moon of terrestrial weather:

The idea that the moon exerts any influence on meteorological phenomena goes back to the most ancient times; there is no belief that has left more traces in the popular traditions in regard to the weather, nor that has been the subject of more controversy.

Let us recall that the time occupied by a true or sideral revolution of the moon is 27d. 7h. 43m., or 27.322 days; the apparent or synodic period, after which the sun, earth, and moon return to their same respective positions, is a little longer, viz, 29d. 12h. 44m., or 29.531 days. It is after this latter interval that the *phases* of the moon again become the same. The *anomalous revolution* or mean value of the intervals of time separating two consecutive passages of the moon through its shortest distance from the earth is 27d. 13h. 19m., or 27.555 days. Finally, the orbit of the moon has a mean inclination to the ecliptic of 5° 8′ 48″; the maximum declination of the moon therefore varies between 18° 10′ and 28° 45′, while the maximum declination of the sun is 28° 27′.

The moon imparts to us only a very small proportion of the light and heat that she receives from the sun. The heat that she sends toward the earth is so feeble that the most powerful instruments and the most delicate methods of measurement must be employed to discover it; there can, therefore, not be any question of a luminous action of the moon and much less of a caloric action,

and we can scarcely think of anything else but an attraction analogous to that produced by the tides on the great masses of water of the oceans. It is therefore necessary to first seek to discover whether the action of the moon does produce atmospheric tides that show themselves by the periodic variations in the height of the barometer.

If we observe the pressure at the lunar hours, that is to say, when the moon passes the meridian and she is distant from it 15°, 30°, 45°, etc., and if we take hourly means of the values observed during a very long period of time, in order to eliminate the disturbances, these means will certainly give an indication of a lunar tide, but extremely feeble; it will only be found at the equatorial stations and disappears entirely in the middle latitudes. At Batavia the maximum pressure occurs a half hour or an hour after the upper and lower passages of the moon over the meridian; the minimum occurs from six to seven lunar hours after the maximum; the total extent of the variation is only 0.11 millimeter, which corresponds to a column of water of about 1.5 millimeter (or one seven-thousandth part of the standard average atmospheric pressure.—Ed.).

The insignificance of the diurnal lunar variation of pressure indicates that this must also be true of the variation corresponding to the revolution of the moon around the earth; that is to say, to the phases of the moon. In Batavia the pressure is the feeblest at the time of the new moon and most powerful shortly after the period of full moon. The total extent of this oscillation does not reach 0.2 millimeter. The diurnal rotation and the synodic revolution of the moon therefore cause tides in the atmosphere as well as in the oceans, but the atmospheric tides are so extremely feeble that they scarcely exceed the limit of accuracy of the barometric observations.

The study of the influence of the synodic revolution or of the phases of the moon upon other meteorological phenomena produces results which are absolutely contradictory, and which have been discussed in detail by Arago and more recently by Van Bebber. We shall therefore limit ourselves to summarizing briefly the conclusions arrived at by them.

The temperature, the cloudiness, and storms do not show any periodicity in relation to that of the phases of the moon. In Germany north and northeast winds seem most frequent in the period of the last quarter of the moon and most rare in the first quarter; the southwest winds show an inverse variation. But this law has not been verified in any other countries.

At Paris and in Germany the maximum number of rainy days occurs between the first quarter and the full moon; the minimum number between the last quarter and the new moon. The relation of the maximum to the minimum is 1.26 at Paris and 1.21 in Germany. It would, therefore, at first sight seem that there is here a true law and that the prospects for rain are greater by a fourth or a fifth after the first quarter than after the last; but even this would be too slight a difference to be made use of for a serious forecast. Besides, this law does not hold good for the south of France. At Orange, for example, the minimum of days with rain occurs between the full moon and the last quarter and at Montpelier in the first quarter. If there is any relation between the phases of the moon and the rainfall, this relation is, therefore, very complex and variable from one region to another.

The study of the changes of the weather has produced still less convincing results. In discussing the observations made at Padua in the last century, Toaldo found that, according to the popular belief, the weather is much more variable at the time of new moon than at the other lunar periods. But convinced in advance of the existence of the influence that he wished to demonstrate, Toaldo attributed to the action of the new moon the changes in the weather occurring one or two days either before or after, whereas for the rest

of the lunar period each day was considered separately. If, now, rigorous computations be made, giving to each day the same value, there will no longer be found any trace of the influence of the phases of the moon on the changes of the weather. During the past few years the study of the influence of the moon has been again taken up in a manner apparently more scientific. In the first place, all idea has been abandoned of finding any relations between the meteorological phenomena and the phases of the moon; that is to say, the synodic revolution which represents only the relative positions of the earth, the moon, and the sun. Then the anomalistic revolution was studied, which corresponds better to the respective real positions of the earth and the moon. But, above all, the position of the moon in declination has been compared, not with any special local meteorological phenomenon—such as temperature, rainfall, changes of the weather, etc.—but with the distribution of pressure over the surface of the globe as a whole.

The fundamental idea of these researches is that the movements of the moon in declination may lead to general displacements of the air or a balancing between the tropical regions and the higher latitudes, and thus cause periodical changes, such, for example, as in the boundary of the trade winds and in the law of change of pressure with latitude. We should then understand that a movement of a zone of high pressure, for example, might cause fine weather on one side of the zone and at the same time foul weather on the other side, and that these variations, which at first sight seem contradictory, might nevertheless be due to one and the same cause. These studies are, however, of too recent date and still too undeveloped to have already given results that may be considered as sufficiently conclusive and general. It is, however, interesting to mention them here, since by continuing to work in the same lines we may, perhaps, succeed in discovering the true relations between the moon and the phenomena of the weather, since the earlier researches have not brought about any positive conclusion. On the whole, in the present state of our knowledge, it can not be affirmed that the moon does exert any influence upon the weather, but at the same time it should not be denied that this influence may possibly exist. In any case it would show itself by complex phenomena, such as the displacement of the zones of high and low pressure, and might cause very different results in different regions.

In concluding the examination of the various opinions in regard to the influence of the moon, it may be well to say a word on the opinions concerning the lune roussée or harvest moon. This name has been given to the lunar period which, beginning in April, has its full moon either in the second half of that month or in the month of May; if there are two new moons in April it is with the second that the harvest moon begins. Agriculturists declare that often at that time, when the sky is clear and the moon shines brightly during the night, the tender buds are frozen and turn red, even although the temperature of the air does not fall below freezing; nothing of this nature occurs if the moon remains hidden behind the clouds. The explanation of this phenomena is very simple and the moon has no part in it. When the sky is clear and the atmosphere dry and transparent (this is the time when the moon shines most brightly), the temperature of bodies subjected to the nocturnal radiation falls far below the temperature of the air. If during the day the temperature has not been very high the nocturnal radiation may then chill the plants below freezing and they will freeze although the air remains at a higher temperature; on the other hand the plants will not be frozen if there are clouds to diminish the radiation. The conditions that lead to these freezings are, therefore, a clear sky and a relatively low temperature during the day. At the end of May or June the mean temperature is generally too high to allow us to fear these

freezes, although they do occur sometimes. Before the commencement of the harvest moon—that is to say, at the end of March or the beginning of April—the temperature is lower than during the harvest moon itself; the conditions are, therefore, much more favorable for freezing by radiation; but as the vegetation has not yet begun these freezes do not cause any damage and do not attract any attention. We have here to do with a very simple phenomenon in which the moon plays no other part than merely to indicate by its brilliancy when the sky is pure and transparent.

In the countries in the south of France, where the vegetation is more advanced than in the center and the north, the critical period of vegetation is no longer during the harvest moon, but during the lunar period which precedes it.

## OPINIONS REGARDING THE INFLUENCE OF THE SUN IN THE PRODUCTION OF RECURRING TYPES OF WEATHER.

Seasonal weather is a product of fixed astronomical causes modified by latitude, topography, and position with regard to land and water surfaces, and a belief is prevalent that departures from seasonal weather is due directly or indirectly to variations in the output of solar energy. There is also an inclination toward a belief that certain aspects of the sun may be responsible for certain types of weather, and it is deemed not improbable that solar conditions of causation may have defined periods of recurrence. At present, however, all is speculation regarding the relation of the sun to possible periodicities of the weather, and the employment of possible synchronous changes in solar and terrestrial conditions in the practice of weather forecasting necessarily awaits an accurate determination and association of conditions and changes of this character. Certain it is that claims of discoveries in this direction that may be made by men of standing in the world of science will be accompanied by proof of the discovery and of its applicability to practical work. In the meantime there are threads or traces of facts that justify further investigation, and in the conduct of this investigation the most approved methods and appliances and a most comprehensive appreciation of the latest advances in practical and theoretical astronomy and meteorology must be employed to achieve results.

Interest in the meteorological possibilities of a study of solar conditions has been particularly active during the last five years, and the literature of this period that summarizes practically all that has been accomplished in this work will be reviewed.

India presents a favorable field for comparison between solar conditions and meteorological phenomena, and the result of systematic and well-directed efforts to associate conditions of the sun, and more especially the appearance and disappearance of sun spots, with unusual delays and early terminations of the southwest monsoon rains is presented in the following extract from a paper by E. Doug-

las Archibald that appeared in Symon's Meteorological Magazine for July, 1900:

* * * Various attempts have been made to correlate the occurrence of Indian famines with the variations in the energy derived from the sun corresponding to the periodic changes in the spotted area; but though there are evidences of parallelism, the relation is not a simple or regular one. The condition of the sun is probably a contributory *vera causa*, but not a *maxima causa*.

Reacting conditions, initially determined by changes in the position of antarctic ice, slight deflections in the equatorial ocean currents and in the vertical and horizontal position of upper atmospheric air streams of abnormal condition, such as those recently shown to exist by means of kite observations, are likely to be far more potent prime causes of seasonal abnormals than the small and fairly regular changes which appear to follow the appearance and disappearance of sun spots. * * *

* * * Apart from these six-monthly barometric waves (referred to as having been observed at times in connection with Indian weather), there is little doubt that certain influences are at work in the atmospheric circulation over the Indian area which cooperate with other periodic factors in tending to cause excess or defect of rains at intervals of nine to twelve years. What these influences are it is difficult to say. To some extent they appear to be associated, as we have above noticed, with the 11-year period of sun spots; and certain irregularities of the two phenomena are, in my opinion, no argument against their convariancy, and even casual connection, since the northern and southern Indian areas are at seasons meteorologically distinct. So far as the facts go they may be summarized as follows:

1. Extensive droughts occur in the dry area of southern India, embracing in particular northern Mysore, south Deccan, southwest Hyderabad, but occasionally reaching Guzerat and parts of the Bombay and Madras presidencies, at intervals of nine and twelve years and usually, but not regularly, about a year before the sun-spot minimum. When the conditions are sufficiently acute famine occurs in the ensuing year.

2. A severe drought in the peninsula of southern India is followed by a severe drought and ensuing famine in northern India in about five cases out of seven.

This sequence is attributed by Mr. Eliot to the empirical law of opposition in the seasonal rainfalls of northern India and the general monsoon conditions of northern and southern India.

Thus a drought and high barometric pressure in southern India usually coincides with low pressure and heavy summer monsoon in northern India. This latter tends to be followed by a heavy winter rainfall, and this again by the compensatory law, first discovered by Professor Hill and the writer in 1877, by subsequent deficient summer rainfall in northern India.

3. Besides these, summer droughts tend to occur in northern India alone in years of maximum sun spots, connected in some way with the abnormal high pressure over western Asia which prevails at such epochs.

There is thus a double periodicity of drought and famine in north India and a single periodicity in south India in the sun-spot cycle, though the relation between the phenomena is too spasmodic and irregular to be utilized as a reliable factor for prevision.

Brückner's empirical cycle of thirty-five years, whatever its cause, undoubtedly exists in the Indian area. Under the title of the "grand cycle" it has long been known in Ceylon, and it is quite possible that the present famine, which from its area and the immense number (6,000,000) of people who are still

on relief works appears to be the greatest famine of which we have any record, may be the aggregate effect of the simultaneous occurrence of a Brückner with a sun-spot cycle drought.

The problem is similar to that of the combinations of harmonic undulations which cause unusual tides, and its solution and application to prevision can only be effected by systematic study of the billows and ripples which appear in the long and short records of barometric pressure over wide areas for many years.

In a paper published by permission of the Secretary of the Smithsonian Institution in the Monthly Weather Review for April, 1902, C. G. Abbot discusses "The relation of the sun-spot cycle to meteorology" as follows:

Since the discovery of the periodicity of sun spots a large space in scientific literature has been occupied by articles tending to establish some connection between this and variable terrestrial phenomena. It is natural that it should be inferred that any considerable change in the sun must bring about numerous direct or indirect consequences upon the earth, but one who has given the subject no attention will be startled to find that the following list contains but a portion of the terrestrial phenomena asserted, on more or less authority, to be influenced by the sun-spot cycle: Magnetic and electrical conditions (including the aurora borealis), air temperature, barometic pressure, humidity, the winds, cloudiness, rainfall, depth and quantity of discharge of rivers, retreat and advance of galciers, number of shipwrecks, bank failures and commercial crises, the crops, prices of grain, famines, wars, and even flights of butterflies.

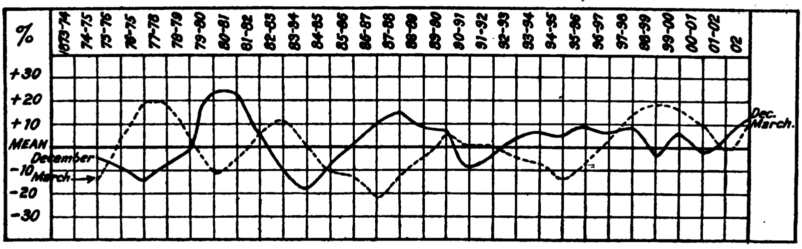
It would probably be easier to show that the number of articles concerning sun spots in scientific periodicals has an 11-year period than to prove all the above-mentioned relations to the general satisfaction. For the purposes of this paper it will be sufficient to assume as proven that terrestrial magnetism and the aurora borealis are affected when spots appear upon the sun, and that while the evidence is less simple in regard to the meteorological elements—temperature, barometric pressure, humidity, cloudiness, and rainfall—yet there is good reason to think that these, too, are somewhat connected with the sun-spot cycle.

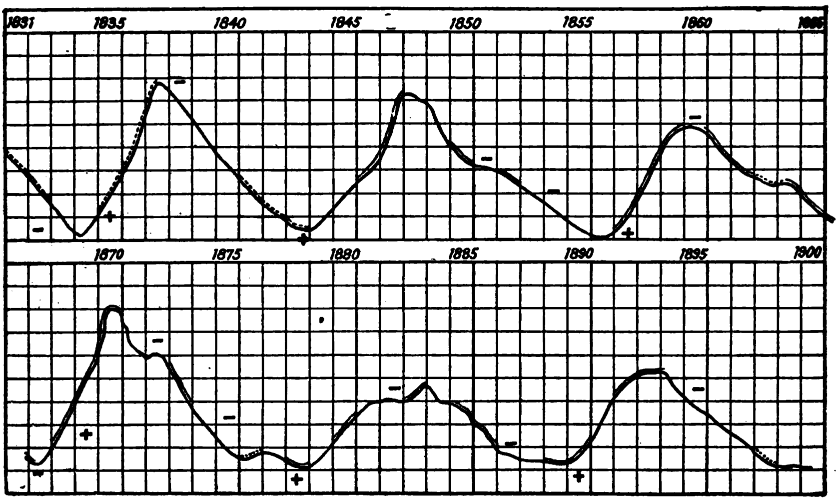
#### HOW SUN SPOTS MAY BE ASSOCIATED WITH TERRESTRIAL PHENOMENA.

The question before us is this: Through what physical connection is the presence of sun spots associated with variations in terrestrial magnetism and with meteorology? The question suggests the possibility either of a single or a dual link between the solar and the terrestrial occurrences. It is conceivable, for instance, that the sun spots are associated with great electro-magnetic disturbances upon the sun which are propagated to the earth and directly disturb terrestrial electricity and magnetism, and that such a disturbance of atmospheric electricity as thus occurs may indirectly induce or prevent the accumulation of clouds, which in turn may bring on differences in temperature, barometric pressure, and rainall. Again, it is conceivable that sun spots are associated with an increase or a diminution of the sun's radiation, which obviously would directly affect meteorology, and indirectly might affect terrestrial magnetism and electricity. Still again, it might be that the sun spots are associated with great electro-magnetic disturbances in the sun and with an increase or diminution of solar radiation, and that in this dual way the terrestrial changes are directly brought about.

The second of these hypotheses is, I think, untenable as an explanation of the magnetic effects. These are too quick and pronounced to allow us to suppose

northwest States and Territories, it would seem that the March curve is very nearly the reverse of that for December. Corresponding curves for June and September are in course of preparation, and subsequently all months of the year will be considered.




It is conceivable that a varying solar heat radiation during a sun-spot cycle may cause appreciable changes in the movements of high and low pressure areas, changes perhaps largely influenced and governed by a fluctuating intensity and position of the subtropical belt of high pressure in corresponding seasons of different years. While the curves already plotted seem to indicate a connection between annual precipitation and sun spots, it is quite possible that a comparison of the corresponding seasons during several sun-spot cycles may show a much more evident connection between sun-spot and meteorological phenomena. Possibly a contraction of the subtropical high during sun-spot minimum may tend to a more than average number of low areas developing in the Southwest while the sun is south of the equator and a diminution in the number and intensity of storms during the warmer seasons when the sun is north.

## STELLAR INFLUENCES AND PLANETARY METEOROLOGY IN LONG-RANGE WEATHER FORECASTING.

The long-range weather forecasts of the ancients, that have in modern times been referred to by uninformed persons as one of the lost arts, consisted merely of an association of the seasons with the

appearance of certain heavenly constellations, and the extent to which seasons were favorable or unfavorable to agricultural or other pursuits fixed the beneficent or malevolent character of the influences that were ascribed to the stars with which they were identified. During the last few hundred years, however, or since the establishment of the sun as the dominating body of the system of which the earth is a part, and since exhaustive tests have shown that the influence of the stars on the phenomena of the earth's atmosphere is practically inappreciable, no serious attempt has been made, even by so-called long-range weather forecasters, to ascribe to the fixed stars a causative influence on terrestrial weather.

Modern advocates of the ancient art of star divination, or astrology, now form a class of fortune tellers whose success depends, as it did thousands of years ago, upon a more or less deeply rooted inherent belief in the superstitions that find lodgment in the average human breast. Trading upon this belief certain men write and talk learnedly (?) and wanderingly regarding eclipses, occultations, and various planetary combinations, accounts of which they cull from almanacs, and ascribe thereto, for a pecuniary consideration received from a credulous or ignorant and unobserving constituency, influences and effects upon our weather that are absolutely hidden and undiscoverable by any known method or system of examination or comparison. These facts regarding alleged planetary influences are presented with an unimpaired belief that they will not in the least weaken the inherent yearning for the mystical referred to, that leads men to subscribe literally and liberally to the support of artful assumers of superhuman knowledge.

Meteorological literature is deficient in references to planetary influences on the weather, and from this fact it may be assumed that long-range forecasters fear to enter a field where deductions are subject to mathematical demonstration, and where claims of superior knowledge will be confronted by established or recognized facts pertaining to the more exact science of astronomy. There are of a necessity exceptions to this rule, and the plea for entering the field is invariably an assumption of knowledge that is universally recognized as being beyond the present scope of astronomy.

In concluding remarks under this head it may be stated that while there is no evidence that the planets of the solar system have a direct controlling influence upon terrestrial weather, arguments have been presented to the effect that they are factors in the production of sun spots and may be, therefore, indirectly and distantly connected with variations in barometric pressure and magnetic force. The connection has not, however, been established; and however fascinating the vision of forecasting possibilities that would result if a knowledge of

the relation of the weather to sun spots could be supplemented by exact calculations of the existence of causes that produce sun spots, the fact that the former connection has not been determined necessarily points to a concentration of effort to solve the first step before advancing to the second step in this extremely complex problem. And it is in the complexity of the problem that long-range forecasters find a refuge. They possess a degree of acumen that enables them to avoid explanations of methods and results along lines where demonstrated explanations are not possible, and to resort to vague references regarding disturbing and imperfectly understood planetary electrical influences, apexes of planetary disturbances, etc., when called upon to explain failures in the operation of their alleged systems or to reply to inquiries regarding the basis upon which they are made.

### WEATHER INDICATIONS AFFORDED BY ANIMALS, BIRDS, AND PLANTS.

Observations of the habits and conditions of animals and birds and the appearance of plants have a recognized value in determining the character of past weather and, to a limited extent, the weather for a few hours in the future. In a state of nature the condition of animals and plants is an indication of the character of past weather, so far as it has affected their physical condition in the one case and their growth and preservation in the other. The appreciation of animals and plants for future weather must necessarily be limited to the effect or influence upon their organizations of present atmospheric conditions, and in the case of animals the sensations that are produced by certain conditions or variations of atmospheric moisture, pressure, temperature, etc., are instinctively associated with the kind of weather that usually follows the kind of sensations experienced. Neither animals nor plants can possibly be affected by the weather of a future month or season.

Undomesticated or wild animals, fowl, and birds are usually used as an observational basis for long-range forecasts. Animals, such as the ground hog, or woodchuck, and the bear, that make winter a season of hibernation, are supposed, by the character of their preparations and the time of their retirement, to indicate the length and strength of the cold of the approaching winter, and toward winter's close they again become prominent factors in this scheme of forecasting. For, according to weather folklore—

If, on Candlemas day the weather is bright and clear, the ground hog will stay in or return to his den, thus indicating that more snow and cold are to come (and there he stays for a period that varies in length in the different sayings that relate to this act from two to six weeks) ; but if it snows or rains he will creep out, as the winter is ended.

The bear comes out on the 2d of February, Candlemas day, and if he sees his shadow he returns for six weeks.

If the sayings regarding the coming out of the ground hog and the bear on Candlemas day possess any merit, it rests upon the fact that fine and clear days in the early part of February are usually cold days, and that cloudy weather at that season is likely to prevail during warm days. The animals in question therefore consult their own comfort in cases where they make a premature exit from winter quarters. If it is cold they return; if it is not cold they remain out until the inevitable return of cold weather, which at that season will not be delayed many days.

The thickness of the fur of fur-bearing animals is also used as evidence of the character of the approaching winter, when, as a matter of fact, this depends absolutely upon "the physical condition of the animal, and his physical condition depends upon the weather of the past and the extent to which it has affected his food supply and general health, rather than upon the weather of the future."

The accumulation of food by squirrels, beavers, and other animals during the autumn months is also taken as a guide to the character of the coming winter. It is assumed that the gathering of a large supply of food indicates a long, hard winter, and vice versa. Careful observations of the habits of animals show that the autumn habits referred to or their omission bear no relation to the character of the following winter. The quantity of nuts stored by squirrels is governed by the supply of nuts at their disposal. In seasons when the crop is abundant the busy little animals will gather a large quantity, and when nuts are scarce his accumulation will be correspondingly small. The supply of nuts is governed by past and not future weather.

Birds of passage migrate to the south with the first breath of winter, or when their food supply is affected by inclement weather that is peculiar to approaching cold weather, and return north when spring sets in in the south. That their flights are influenced by present rather than a knowledge of future weather conditions is evident to all observers. Their judgment is on a par with that exhibited by some men in doffing or donning winter clothing; their actions are dictated by a sense of personal comfort, and they are often compelled by actions to admit their error. The thickness of plumage on wild and domestic fowls is also a result of feeding and past conditions of weather, rather than an indication of the character of future weather. And the goose-bone theory is one on which no two geese agree.

Moss, bark on trees, and the thickness of nut shells, pumpkin rinds, etc., furnish another basis for long-range weather speculations that also confuse and misinterpret conditions that are due to past conditions and have no bearing on future weather. There is one feature of tree weather forecasting, however, that possesses merit in so far as it presents as a basis a record of the general character of the weather for

many years, and may thus show or indicate recurring seasons of certain kinds of weather. Trees of great age and large growth, like the sequoias, indicate by their rings years that have been favorable and unfavorable for their growth, or, in other words, wet and dry years in the region in which they are located, and thus establish a record of the seasons that may be useful in calculations for the future.

In passing, it will be noted that prominent advocates of this branch of long-range weather forecasting have long since disappeared from public view, which fact may be taken as indicating that dishonest practices can be profitably conducted only by the possession, or an assumed possession, of superior knowledge, or under a cloak of mysticism, and not in connection with matters concerning which ordinary observation will reveal the truth.

### ESTIMATES BASED UPON DAYS, MONTHS, SEASONS, AND YEARS.

There are several valid reasons for assuming that the weather observed on certain days may indicate the character of the weather for certain subsequent days. The first of these is that in the middle latitudes of the globe well-defined atmospheric disturbances or general storms of greater or less intensity average about one in each six or seven days; the second, that marked departures from the average weather occurring on one day, or on two or three consecutive days, are likely to be balanced by reverse abnormalities in the near future; and the third, that the general average duration of warm waves and cold waves, which are attendant features of areas of high and low barometric pressure, is three days. The seven-day period also corresponds closely with the moon-phase periods, which admittedly have a slight effect upon rainfall (too slight, however, to be considered in daily forecast work).

The assumed or supposed six or seven day period of recurring weather is indicated by the common saying, "If it rains on the first Sunday in the month it will rain every Sunday in the month." This saying possesses value in so far as the weather may conform, in particular instances, to a general average, and the likelihood of the weather conforming to this extent to general averages is not sufficiently great to justify the employment of the chance in actual forecast work. Forecasts for two to three days in advance, made in the full light of present knowledge, must be based upon actual existing atmospheric conditions that prevail over great areas, and they represent calculations of changes that will occur within the areas; they deal with average conditions only so far as a recognized tendency on the part of the weather to return to average conditions may be considered. Sunday was doubtless selected, in the saying quoted, for the reason that the weather and its seasonal or unseasonal character is more closely observed and studied on certain days, notably on Sun-

days and holidays, when men's minds are not occupied with their usual pursuits; any other day in the week will answer as well for this form of estimating the weather of the future.

Long-range weather forecasters, for purposes of mystification, attribute the six and seven day period to the moon's influence. They time their disturbances six or seven days apart, start them on the Pacific coast and carry them by regular stages across the United States, assuming in each case a conformance to general averages. Equal accuracy or inaccuracy in the forecast would result if they started the disturbances in the central valleys or on the Atlantic seaboard on corresponding dates, or introduced them on the Pacific coast on dates intermediate to those they select. By claiming, for verification purposes, a day or two on either side of the dates specified, by carefully avoiding specific forecasts of rain for specified days and districts, and by calling attention to hits that will occasionally be made under any system of chance, and never referring to misses, they successfully pursue in these enlightened times the practices of the fabulous age.

The six and seven day weather periods have been subjected to a rather searching examination by H. Helm Clayton, and the results of his examination are given in several publications, but principally in the American Journal of Science and Art. It may be noted in this connection that Mr. Clayton for a time actually published forecasts based upon his conclusions, which were not, apparently, satisfactory as regards results nor convincing as regards a confirmation of any theory he may have held.

Investigations and conclusions based upon honest and thorough examination and comparison of meteorological records show that generally recognized, though ill defined, six and seven day periods of recurring weather can not be utilized for making definite forecasts for specified days and localities. Assuming that forecasts of rain or fair weather, warmer or colder, based upon the results, would yield a slightly higher verification than unqualified guesses—which, if made in sufficiently large numbers, would naturally verify in one-half the cases—there is no evidence presented by the investigations that the character or intensity of the disturbances that attend the barometric minima can be determined. A knowledge of the probable order of succession of barometric depressions for periods of one to four weeks in advance would greatly assist the forecaster, and as a matter of fact the probability of the succession has been given due weight and consideration by the Weather Bureau for many years. Experience in actual forecast work has shown, however, that rules that are subject to 50 per cent of exceptions are, like theoretical deductions, dangerous factors to employ in the work of weather forecasting. And aside from conclusions that have been or may be reached regarding systems or methods of forecasting merely weather and temperature,

the fact remains that forecasts of this class are of small importance when considered in connection with forecasts of severe storms, etc. In fact, the value of weather forecasts is fixed by the degree of accuracy that is attained in predicting gales, cold and warm waves of marked severity, heavy snow, heavy rain (and floods resulting therefrom), frost, and other atmospheric phenomena of an unusual or exceptional character, and long-range forecasts that are calculated to be of special value to commercial and agricultural interests must specify these occurrences for specified sections, and to this end honest endeavor is being directed.

A casual examination of published long-range weather forecasts shows clearly that the success of the systems depends absolutely upon a conformance of the weather to six or seven day periods with modifications called for by seasonal averages and chances, and the fact that in about 50 per cent of the cases the periods are not revealed and that fully one-half of the forecasts are misplaced in the periods that do appear proves to conservative minds the unsoundness of the systems. It is apparent from reports of investigations that have been made that there is a tendency on the part of investigators to assume the six and seven day periods and to then endeavor to fit the periods to moon phases or positions, solar rotations, etc.

Estimates of future weather that are based upon the character of certain days have their origin in fancy or superstition. As a rule the days selected are church or saints' days or holidays, and it is apparent that the selections have been governed by the prominence of the days. As a basis of calculation the weather of certain days is of value—

only so far as it may be assumed that normal weather conditions on those days are favorable and abnormal conditions are unfavorable for seasonable weather in the near future. They may be considered as indicating which way the balance of temperature and precipitation tips at that particular season of the year, and the forecasting feature is found in the statement of weather conditions that will be required to adjust the balance.

Individual months are taken as a basis of prediction for succeeding months or seasons, and all estimates of this character that possess merit speculate merely on normal tendencies of the weather at certain seasons, and, like estimates based upon the character of days, assume that normal conditions are favorable and abnormal conditions unfavorable for seasonal weather in future months, seasons, or years. In fact, the entire scheme of long-range forecasts that are based upon the condition of the weather during certain periods, whether long or short, depends upon an assumed inviolable law of compensation. This assumption is, in a degree, justified, but for purposes of specific forecasts it possesses little value. Records of meteorological observations taken at given points show that the temperature and rainfall of single years and series of years conform closely to normal values and that

the greater the period the smaller are the departures. Conversely, the shorter the period the greater the departures that are sometimes shown, until for periods of a month or less it is impossible to calculate to what extent abnormal features may predominate. There is a popular impression that a warm winter will be followed by a cool spring or summer, and a hot summer by a cool autumn or winter, but the succession so indicated will not occur in more than 50 per cent of any large number of cases that may be noted. The question may here arise, How, then, can compensation be made for extreme abnormal conditions for days, months, or seasons? The answer is that it is not necessarily made in any one month, season, or year. For instance, in the Middle Atlantic States the summers of 1901, 1902, and 1903 were cool, and the winters of 1900-1901, 1901-2, and 1902-3 were moderate, while the winter of 1903–4 was probably the coldest in the history of that section. The question now arises, What period in the preceding three years could have been used as a basis for forecasting an exceptionally cold winter in 1903–4?

Examinations of records show that excesses or deficiencies of temperature or rainfall in any season do not necessarily indicate opposite excesses and deficiencies for any given future period, and that when compensation is made for excesses or deficiencies it is made gradually and almost imperceptibly as often as in the form of marked opposites.

## PREDICTIONS BASED UPON OBSERVATIONS OF OCEAN CURRENTS.

The influence of ocean currents, notably the Gulf stream and the Japan current, upon the weather and climate of western Europe and western North America, respectively, has been discussed in numerous papers, and the belief has been expressed that observations of variations in the Japan current could be made a basis for forecasting California weather for several months in advance. The opinion has also found expression that the course of the Gulf stream, with particular reference to its north and south shifting over the western Atlantic, had a controlling influence upon West Indian hurricanes and even furnished a basis for predicting their periods of frequency and intensity.

The general subject of ocean temperatures and meteorology, based upon a paper by Sir John Murray that appeared in the Geographical Journal for August, 1898, published by the Royal Geographical Society of London, is considered, in brief, in the Monthly Weather Review for July, 1898. After summing up data of ocean temperatures and comparing these temperatures with those obtained over the continental areas, the editor of the Review concludes as follows:

At first thought one would expect to find in Doctor Murray's lines of equal annual temperature range some traces of the course of the Gulf stream and Kuroshiwo (Japan current), but it is only the changes in the positions of these

currents that can produce ranges of temperature, and these changes are so largely controlled by the wind that Doctor Murray's charts show us principally the effect upon the ocean water of the changes in the atmospheric circulation. This same principle applies also to the closed seas, such as the Mediterranean and Baltic, the Red Sea, and the Persian Gulf, in all which cases a larger range of temperature is observed at the head of the sea than at the mouth of the sea, due to the fact that the highest temperatures occur at the head when the wind blows toward that direction in the summer, and the lowest temperatures when the wind blows in the opposite direction at the opposite season of the year. There is, therefore, in this map no comfort for those who maintain that the Gulf stream or the Kuroshiwo, respectively, alleviate or control the temperatures of the eastern portion of the Atlantic and Pacific oceans and the adjacent portions of Europe and America, respectively. Everywhere we see that it is the wind that controls the temperature of the surface of the ocean, and then carries this ocean temperature inward over the land. The same applies to the Southern Hemisphere, where Doctor Murray's chart shows that the greatest range of ocean temperature is in the regions where there is the greatest annual range of wind direction.

In the August Review of 1898 Professor Abbe refers as follows to studies of the Japan current:

We notice in several California papers earnest articles advocating the study of the Japan current and its relation to the weather of the Pacific coast. Especially does Mr. W. S. Prosser, of Auburn, Cal., state that in 1878 or 1879 he suggested this very thing and urged favorable action on the authorities at Washington.

It ought hardly to be necessary to assure the citizens of the Pacific coast that the Japan current, like the Gulf stream, has been studied with much care by the navigators of all nations, and charts have been published showing the temperature and the movement of the surface water, not only for these special currents, but for the whole of the surrounding ocean for each month in the year. These charts show that without any doubt whatever the currents as such soon dwindle away, and all that is left is a very slow movement of the water to and fro with the wind. It is the west wind that strikes our Pacific coast, and not the Japan current. This wind brings moisture from the Pacific Ocean, and not from the neighborhood of Japan. It is these moist winds, and not the ocean currents, that control the climate of California.

The hydrographic offices of all nations are engaged in the study of ocean currents and surface drifts as such, including their dependence upon the winds. The meteorologist studies the winds as affected by the surfaces of the land and ocean, but he finds the atmosphere moving so rapidly and its various portions so easily intermixed with each other that it is at present impossible to tell whether the moisture brought by the wind to California comes from the Pacific Ocean in general or from the Japan current especially. In fact, it matters little to him where it comes from. He has to take it as he finds it over California, and then decide whether it is rising and cooling to form cloud and rain, or whether it is descending and likely to stay unprecipitated. The important features of the weather of California depend principally upon whether its winds are descending and being pushed outward from a high and dry area to the northeastward, or whether they are descending and coming from moister air to the northwestward. It is the air supplied from the high-pressure area on the southwest, between California and Hawaii, that gives the former her long-continued spells of dry, clear weather. The length of these spells may

depend, in a general way, upon atmospheric conditions, not on the condition of the ocean.

In the fall of 1898 the writer remarked on the Japan current as a controller of California weather as follows:

> The subject of long-range weather forecasts has recently gained attention by reason of a suggestion of Professor Hammon, of the Weather Bureau office at San Francisco, that possibly the character of the seasons in California can be successfully forecast by a study of the Japan current.
>
> In examining reports of meteorological observations made in the Aleutian Islands he discovered an apparent relation between abnormal air temperatures in those islands and periods of drought and excessive rainfall in California. He associated unusually high temperature in the north with subsequent periods of drought in California, and unusually low temperature in the north with excessive rains in California. In seeking an explanation of these apparent relations he concluded that periods of high temperature in the Aleutian Islands indicated a northern course of the Japan current, whereby the heat of that current was, in part, lost, causing it to arrive off the California coast possessed of unusually low temperature, giving drought in California; and that abnormally low temperature in the Aleutian Islands indicated a southern course of the Japan current, which, in following this course, retained its heat and arrived off the California coast possessed of unusual warmth, thereby causing excessive rains in California. He calculated that if the succession of these conditions could be established by further observations, three months' foreknowledge of the character of the weather in California could be given and that the fruit and grain industries of that State would be benefited by the forecast to the extent of millions of dollars annually.

Professor Hammon's merely preliminary investigations, and the theory which has evolved from them, naturally lead to the question, Can long-range forecasts of California weather be based upon observations taken along the Japan current? The solution of this question is dependent upon the establishment of the following facts: That there are periods during which the water of the ocean off the California coast is unseasonably warm or cold, that these periods are associated with periods of excessive rains or drought, respectively, in California, and that periods of warm and cold ocean temperature and of excessive moisture and drought in California are associated with periods of abnormally low and high air temperatures at points in the north which border the course of the Japan current.

As regards the first fact to be established, there are no known data which show that the temperature of the ocean water off the California coast is subject to unseasonable or abnormal changes in temperature; and we are not permitted to associate possible but unknown changes of this character with California climatic changes, nor with abnormal air temperatures over the Aleutian Islands. We are, in fact, confined to an attempt to associate periods of unusually high and unusually low air temperatures over the Aleutian Islands with periods of drought and excessive rains in California. Owing to very meager data it is not possible to establish these relations; it is not possible to

say whether the apparent relations discovered by Professor Hammon were accidental or resulted from a law of nature.

In the Philadelphia Press of October 5, 1898, Mr. Harvey M. Watts remarks upon the deductions of Mr. Hammon regarding the influence of the Japan current on California weather as follows:

The Weather Bureau has had the question of long-range weather forecasts once more brought to its attention by the California State Board of Trade. Every once in a while the problem and possibility of seasonal forecasts is discussed but to be negatived by present knowledge. That an approximately correct seasonal forecast would be of enormous benefit to agriculture is unquestioned, and it is this that impels the Californians to ask the Government experts to look into the matter, for they believe that the observer at San Francisco, Mr. W. H. Hammon, has discovered the determining factor in the seasonal variations of California weather. With this factor known and its variations recorded the possibility of forecasting wet and dry years opens up a new future for agriculture, as it reduces useless experiment and heavy losses due to climatic vagaries.

The seeming fact that has been worked out by Observer Hammon is that there is a close connection between the shifting of the Japan oceanic current and the wet and dry seasons along the Pacific coast. When the Japan current is deflected to the north, according to Mr. Hammon's theory, it gives up its warmth to those regions and arrives off the Pacific coast cooled down to such a degree that little evaporation results and the year is dry. If the current keeps moving along the lower latitudes its effect is felt in the increased warmth, moisture, and precipitation along the lower Pacific coast line and a wet year is experienced. This relation, as determined by Mr. Hammon, takes three months to show its effects, so that the Californians believe that a cable laid to one of the Aleutian Islands would enable the United States observer at San Francisco to forecast the summer conditions for California by a study of the spring conditions 2,000 miles to the northwest. In this way millions might be saved by means of a general seasonal forecast, which would enable agriculturists to prepare for the worst or make ready for a bountiful return under favorable weather conditions.

Without going into the merits of Mr. Hammon's deductions for the moment, it should be said that extended observations either with or without a cable in the Aleutian archipelago will well repay any outlay the Weather Bureau may ask Congress to make. Not only the Pacific coast weather, but the seasonal conditions of the entire Northwest, the upper Mississippi Valley, and, to a certain extent, the watershed of the Great Lakes are forecast in the conditions that prevail in the northern Pacific Ocean. It is from the northern Pacific that the continental storms move in that play so important a part in the climatology of the United States. And it is the shifting of these oceanic areas of low barometer relatively to the high barometer over the interior of the continent in British America that makes up the alternations of warm and cool, wet and dry weather that are daily displayed on the United States weather maps. To attribute the variations of climate due to these great atmospheric swirls to an oceanic current, however, seems an error, though it is the same kind of an error that for so many years attributed to the Gulf stream a determining effect on the climate of all western Europe. As the results are out of all proportion to the cause, the Gulf-stream theory has been generally abandoned, and it would seem that Mr. Hammon's Japan-current theory would suffer a like fate, for it is the general eastward atmospheric drift and not the trend of the oceanic currents that determines the climate.

However, even if one throws overboard the Japan current, it does not in the least destroy the possibility of forecasting weather conditions in the United States by means of observations in the Aleutian Islands. There our weather is brewed. There the great changes occur—the deflection of the Japan current probably being an incident—that are felt later on our coast and continent. To study them, to discover any rhythm in their yearly or secular variation, is to get at the secret of long-range forecasting. This work is one of vast importance, not only for California but for the greater part of the United States, where the weather is controlled by the circumpolar circulation. To make sure, however, of the accuracy of these seasonal forecasts a wide outlook must be maintained. In India, the only country where such forecasts are attempted, the atmospheric conditions over Persia, southern Africa, and Australia play an important part in drawing conclusions. For us it must be the northern Pacific and the Athabascan region. And to get at the former let us have the Aleutian stations by all means.

In a letter dated February 19, 1904, the honorable Secretary of Agriculture answered a communication of Mr. W. S. Prosser regarding the importance of investigations of the influence of the Japan current on the weather of the Pacific coast of the United States as follows:

Your letter of the 8th instant, urging the importance of studying the influence of the Japan current upon the weather conditions of the Pacific coast, has been received and given careful attention. You are quite right in your statement that an accurate forecast of the rainfall of California a season in advance would be extremely valuable to the people of that State. I can not assent so readily, however, to your second proposition, viz, that the climate of the Pacific coast depends upon the Japan current, as that of England depends upon the Gulf stream. Persons who have given the matter careful study and should, therefore, be in a position to speak advisedly are not willing to admit that either the Gulf stream or the Japan current, as such, exerts any appreciable influence upon the climate of the shores opposite its origin. It is quite true that the general oceanic influence is a powerful one on the shores of western Europe and western America. The popular error in regard to the matter is twofold in its nature. In the first place, the public generally has a very inadequate idea of the true nature of both the Gulf stream and the Japan current. The mistake is generally made of giving both of them throughout their entire course attributes which they possess only at and near their origin. In the second place, the popular mind ascribes to the two currents under consideration, which form only a small part of the great oceans in which they course, effects which truly belong to the oceans as a whole and not to an insignificant part of them. Within the last half century organized effort has been put forth in various parts of the world to obtain accurate data as to the weather conditions and currents of the great oceans.

Out of all this effort has come certain facts that satisfactorily explain the broader principles of oceanic circulation. First and foremost of these is the effect of the wind upon the ocean waters. Throughout a broad belt on the earth's surface, say from twenty degrees south latitude to thirty degrees north latitude, the winds are persistently from some point in the eastern semicircle, and it is in this region that the great oceanic currents have their origin. In the Northern Hemisphere the surface waters, under the influence of the northeast trade winds, have a decided set from the northeast or east, and there is formed what is known in both the Atlantic and Pacific oceans as the north equatorial

current. This current, or drift, as it might be called, is due to the direct action of the wind on the water. In the North Atlantic the surface drift from the northeast heaps up the water in the Caribbean Sea, and since it can not escape to the westward the overflow is forced to the northeastward through the Florida Straits, and thus forms the Gulf stream. This stream, as it emerges from the Gulf of Mexico and passes northward between Florida and the Bahamas, is only indirectly caused by the wind. In its lower reaches the wind is powerless to change its direction, but it may, and often does, accelerate or retard its velocity. In the North Pacific Ocean the north equatorial current impinges on the eastern shores of Formosa and adjacent islands, the greater portion, however, passing into the China Sea. The remaining portion is deflected northward along the eastern shores of Formosa until it reaches about twenty-six degrees north latitude, where it bears off to the north-northeast, washing the southeastern shores of Japan and then moving northeastward with diminishing velocity it merges with the general easterly drift of the North Pacific.

The existence of the so-called Japanese current in the North Pacific is perpetuated during the season from March to September by the prevailing southwesterly winds, but when these fail, as in the months of October to February, the current as such becomes uncertain and variable, its direction and velocity depending largely upon the wind experienced from day to day. I have entered into this detail in order to make clear that the great ocean currents are created primarily by the wind, and that in themselves they can not have the dominating influence on the weather that is often ascribed to them. The influence of the Pacific Ocean on the climate of California is, of course, understood. It tempers the winds of winter and protects a large portion of the State from frosts and snows normal to the latitude, and in summer the moist, cool winds bring cloud and fog along the coast, and this it does from year to year without perceptible change. The great ocean itself, with its thousands of miles of water surface, is the important factor as regards the climatology of the State. The temperature of the ocean waters changes but little from year to year; whatever slight variation there might be in the temperature of the so-called Japan current would not, it is believed, have the slightest effect on the rainfall of California a year hence. I do not underestimate the value of seasonal forecasts, nor am I unwilling to set on foot investigations that give promise of even a small degree of success. The progress of science is necessarily slow, but let us continue to hope that the problem may be eventually solved.

For further information relative to the effect of the oceans on land climates you might read an article by Professor Moore, Chief of the Weather Bureau, in Encyclopedia Americana, a publication just now coming from the press.

## A CONSIDERATION OF ATMOSPHERIC PRESSURES IN WEATHER FORECASTING.

Many well-informed meteorologists are of the opinion that the next advance in the art of weather forecasting will be accomplished by a correlation of the greater and lesser areas of high and low barometric pressure of the Northern Hemisphere or of the globe. The forecasts now issued by meteorological services are based upon skill acquired by study, observation, and experience in calculating the development, movements, increase, and decrease in intensity, and magnitude of areas of high and low barometric pressure that appear within areas covered by the telegraphic reports of the several serv-

ices. The dependence of these lesser high and low areas upon the greater or continental and oceanic so-called permanent areas of high and low barometric pressure is recognized, and the fact is admitted that a knowledge of the character and movements of the greater masses of the earth's atmosphere, as represented by the continental and oceanic seasonal high and low areas, is essential to calculations of weather conditions in any given section or locality for periods greater than two or three days in advance. For it is apparent that upon the exact location and magnitude of these greater high and low areas for a day, week, month, or season does the character of the weather in the regions they dominate depend. For instance, a slight shifting to the westward of the summer North Atlantic high area gives unusual heat and generally dry weather over the eastern portion of the United States. If the center of the high area shifts to the westward south of its usual position, as regards latitude, the heat is general from the Gulf of Mexico to Canada; if the center occupies a more northern latitude in its western position the heated area is confined to the more northern districts of the eastern portion of the United States, and the South Atlantic States receive the benefit of easterly winds from the ocean. When the Atlantic high area occupies an easterly position over the ocean, or exhibits pressures below the normal, cool weather for the season, or at least variable temperatures, are experienced over the eastern portion of the United States. In fact, the North Atlantic high area controls to a great degree not only the summer weather of the greater part of the United States, but also the course and character of West Indian hurricanes.

Winter types of weather over a great part of the middle circuit of the Northern Hemisphere are undoubtedly dominated in a greater or less degree by the great Asiatic area of high barometric pressure. In the middle latitudes the movements or swingings of this vast mass of air is to the westward; when it moves or extends over the northern portion of Europe North Atlantic storms are likely to be deflected toward southern Europe, and cold, stormy weather is experienced over southern European countries; when it extends westward over southern Europe North Atlantic storms follow a course toward the Scandinavian coast, and moderate temperatures are experienced in central and southern Europe. When the great continental high area extends westward over west-central Europe and the British Isles it checks the succession of North Atlantic storms, and finally affects the rate of progression of high and low areas over the United States. In its normal winter distribution atmospheric pressure is higher over southern Europe and relatively low over the northern, and especially over the northwestern countries. Under these conditions of atmospheric pressure the progression of storms from the Atlantic is normal; when, however, this arrangement of pressure is reversed or dis-

torted, abnormal storm movements and features will be observed. At times, also, when the air masses up over western Asia and continental Europe the advance of Atlantic storms is checked, resultant low barometric pressure prevails for periods of several days over and near the British Isles, high pressure builds up over the middle longitudes of the Atlantic, and the eastward progress of high and low areas over the United States is retarded. It has been found by observation that this retardation of the usual progression of high and low areas over the eastern half of the United States continues several days after evidence appears of a return to normal barometric conditions over western Europe.

The influence of the Asiatic winter area of high atmospheric pressure is recognized in all studies and calculations regarding Asiatic weather and climate. The spring and autumn monsoons of the southern countries of Asia are directly associated with the breaking up in the spring and the building up in the autumn of the great interior air mass, and a solution of the problem of forecasting the time and character of the monsoons rests upon the ability of the meteorologist to foresee the nature of the changes that occur in Asiatic atmospheric pressures.

## OPINIONS AND DISCUSSIONS OF THE GENERAL SUBJECT OF LONG-RANGE WEATHER FORECASTS.

Under the title "Imperial meteorology," in Nature (vol. 69, pp. 537–538), recent progress in meteorology is discussed as follows:

Slowly, but still step by step, the science of meteorology progresses, and new visions are opened up which suggest bright prospects for future possibilities, but which also lay exposed the lost opportunities of the past. Like every other science, the modern methods of observation (or at any rate the chief meteorological elements) are nearly all that can be desired, but when it is required to revert to observations made more than thirty or forty years ago, how lamentably few are the records and how uncertain in many cases are their accuracy. Further, anyone who has had occasion to hunt up early series of observations of pressure, temperature, rainfall, etc., will have been struck with the common occurrence of breaks extending here and there for one, two, three, or more years. Nevertheless, it is little use crying over the past, but strenuous efforts should be made in the future to see that the needed observations should be secured.

The more the variations of the weather are studied the more is the idea strongly impressed on the investigator that these variations from year to year are not mere matters of chance, but are produced by a cause originating outside the earth's atmosphere, and with little doubt from the sun, naturally the prime factor and father of all the important weather changes.

His apparent daily journey round the earth, caused by the latter's rotation, is the origin of all the diurnal changes familiar to meteorologists.

The earth's journey round the center of our solar system is again the origin of all the other meteorological variations called seasons which pass through their phases in a year.

From year to year, however, these daily and yearly variations, although they preserve more or less their original variations as regards their lengths of period, change in amount sometimes to a very great degree and cause one to speculate on the probable kind of weather for the following year.

The view that these changes from year to year are due to the direct or indirect action of the sun has a very great degree of probability in its favor, since we know that this highly heated body is in an active state, as deducted by the numerous and varied solar phenomena that have been observed. Further, the periodicities deduced from long series of solar observations have added another link in the chain of evidence showing that the sun's heat must be constantly varying, a fact which it is necessary to prove before solar influence can be put forth as a possible source of the terrestrial changes.

It is the work of the now numerous magnificent meteorological institutions spread over the globe for each to gather into its own particular net the meteorological changes that are occurring in its own area, and by means of these facts to forecast what kind of weather may be expected either on the following day, week, or month, or as far ahead as possible. Many of these institutions for several years found that their own areas were too limited in extent to give them the necessary data for the work in hand, and so entered into a mutual compact with neighboring countries for the exchange of certain pieces of meteorological information.

The present stage of meteorological investigation has in the last few years indicated that even this mutual help of the neighboring countries, each working for its own immediate ends, is not sufficient for a satisfactory solution of world meteorology.

" The next development of weather study will almost certainly be in the direction of international or world meteorology and its relation to the phenomena of sun spots and terrestrial magnetism.

" World empire entails world duties, and one of these appears at the present time to be a study of meteorology from the imperial and not solely from the national or parochial standpoint."

In his annual report for 1903 Professor Moore, the Chief of the United States Weather Bureau, refers to the problem of seasonal forecasts for a year, as follows:

It is a difficult piece of science that is involved in the attempt to place the forecasts of the seasons for a year in advance upon a reliable basis, because it may be necessary to take account of several interrelated processes in nature which depend upon the circulation of the atmosphere of the sun and of the earth. The science of meteorology is not to be confined to the atmosphere of the earth, because the changes in the action of the atmosphere of the sun precede the variations in the earth's air, which finally culminate in a certain type of season. Thus, wet and dry seasons, warm and cold summers and winters, and all the other climatic differences first depend upon the persistence of special high and low areas of pressure in one locality or another; these go back to the circulation of the great currents in the atmosphere, which seem to surge back and forth from one side of the earth to the other, or from the oceans to the continents; finally, these currents may be due to the solar radiation, which itself changes with the output of energy from the interior of the sun.

Thus, meteorology is really a very closely allied but difficult branch of solar physics, and it ought to be studied with the aid of a fully equipped observatory devoted especially to such researches. On the sun we count up the number of

hydrogen flames or prominences seen on the edge of the disk from day to day, and, from a discussion of the thirty years' record in hand, they are known to vary strongly from year to year. Similarly, the faculæ and spots have their fluctuations in synchronous cycles, and these have been studied for many years. Furthermore, the sun emits energy in the form of radiant light and invisible heat, and by means of suitable spectrum observations the variable amount of this light, and especially the invisible heat, can be registered from day to day and from year to year. The result of these records is to indicate that the sun is in fact a great, variable star, and that terrestrial weather may change in close synchronism with it. There is yet another register of the energy emitted by the sun to be found in the variations of the earth's electrical and magnetic fields, which is perhaps the most sensitive of all, and certainly the most accessible to our measures. The newly discovered action of ions in the atmospheres of the sun and the earth, respectively, which are now believed to be the basis of the electrical and magnetic manifestations, is affording much information upon this obscure subject, and it is full of promise in practical investigations. Langley has announced that the invisible radiant heat energy, as measured in his bolographs, varies from season to season and from year to year. The passage of an eclipse shadow through the atmosphere changes the atmospheric magnetism and electricity in the same way that day and night modify them—by cutting out the sun's rays. In short, the entire field of cosmical processes forms a complex problem which especially concerns the meteorologist, and by him should be studied out for the benefit mankind, whose life and happiness depend so largely upon the weather.

The Weather Bureau is so far convinced of the importance of finding out the laws of this cosmical physics, by which alone the problem can be conclusively solved, that it has been thought proper to found a research observatory at Mount Weather, on the crest of the Blue Ridge Mountains, about 6 miles from Bluemont, Va., and equip it suitably for these investigations. It is evident that such an institution, having its beginning in the early years of the twentieth century, will have an increased usefulness as the years go by if it is organized according to the demands of the best science. It will require fine instruments and able students if it is to command the respect of the scientific world. The subject of solar physics has already grown to such proportions that the British Association for the Advancement of Science has set off a solar-physics section from astronomy and mathematics; the solar-physics observatory at South Kensington, under the able direction of Sir Norman Lockyer, is putting forth valuable results; the solar observations by the Italians for the past thirty years have become invaluable as a basis for these studies; the observatory at Kalocsa, Hungary, and that at Zurich are known to all students for their important publications. Less directly, several of the great astronomical observatories are deriving some of their most valuable discoveries in astrophysics, which is simply another name for stellar meteorology. Thus Potsdam, Paris, Lick, Yerkes, Harvard, and other institutions are working zealously along these lines and filling out the realm of human knowledge in a fashion undreamed of a generation ago.

It may be asked why, with all this wealth of material being secured in other places, it should be important for the Weather Bureau to enter upon these studies as well. The answer is simple. These observatories, for one thing, specialize along certain lines, and it is evident that there should be at least one institutions in the United States where these results are brought together and studied side by side, so that their combined result at any given time can be worked out harmoniously and correlated with the prevailing weather condi-

tions. Furthermore, the publications of these several observatories are issued from the press as much as two to four years after the observations are actually made, so that it is obvious that these late reports can have little value in practical forecasting. We have no intention to enter upon the advanced research problems which rightly belong to specialists, but rather to adapt to the uses of the meteorologist and the forecaster such portions of the well-known types of observatories as seem to be practicable for the immediate uses of the Weather Bureau.

Specifically the plan in mind contemplates the development of an observatory as indicated in the following statement:

(1) An observatory building is in process of erection at Mount Weather, which is well adapted as a school of instruction and for making observations of the ordinary kind with the common meteorological instruments, barometers, thermometers, wind and rain gauges, nephoscopes, theodolites, and actinometers. The first floor is for administration, the second for living quarters, the third for laboratories, and the roof for observing.

(2) Plans are being prepared for a plant adapted to generate large quantities of hydrogen for balloon ascensions, including a shop for the construction of balloons and kites. The ascensions will be limited to about 4 miles in height, our immediate purpose being to measure the temperatures and thermal gradients, which will enable us to construct daily isothermal charts on the two upper planes already described so as to provide isotherms as well as isobars on the high levels. It is proposed to make a complete series of ascensions first at Mount Weather, and afterwards in different portions of the United States, in order to observe the temperature conditions in all classes of cyclones and anticyclones. We may attempt some high ascensions, up to 10 or 12 miles from the ground, when our experience and other conditions warrant, but since storm movements are practically limited to the strata within 4 miles of the ground, the first group of ascensions will be to moderate elevations.

(3) It seems important to install a high-grade bolometer for measuring the invisible solar radiation, which is thought by some students to be largely responsible for the actual temperature of the upper atmosphere. Also a first-class spectro-heliograph is required for keeping a record of the solar prominences, faculæ, and sun spots prevailing at the time of making our weather forecasts. These two instruments are the essentials of an efficient solar physics observatory, and would require the services of an able student of physics to bring out the best results and discuss them efficiently in suitable reports.

(4) These records should evidently be supplemented by an observatory equipped with modern instruments for observations in atmospheric electricity and in magnetism, and we note that a number of valuable new instruments have been invented in recent years which we can use. The special subject of this research is the behavior of ions in the atmosphere as forerunners of weather conditions.

Generally the idea is to bring together for study under one direction the most valuable and practicable observations having a direct bearing on the higher meteorology, which is now engaging the attention of many able physicists and astronomers. In this field are found the best examples of physical and mathematical problems, because it is nature's great laboratory. The atmospheric conditions at Mount Weather are superb, the site being 1,800 feet above the sea level, on a ridge overlooking the wide Shenandoah Valley to the west and the plains of Virginia to the east. An equipment at that place, such as is contemplated, will induce a great scientific activity and generate an intellectual atmos-

**phere highly favorable to the best scholarship. The assistants in charge of the various lines of work will form a strong corps of teachers, who will instruct a new generation of men in the great problems of meteorology, which are destined to occupy the attention of mankind in an increasing ratio with the lapse of time. If the equipment be made up of the very best instruments and able students secured to use them, and especially if patience be manifested in allowing the data to accumulate and be studied in the proper way, an improvement in forecasting for America should be assured. This institution is to be planned for continuous work in the future, and it is not supposed that its effect on forecasting will be immediately manifest because of the difficulty and complexity of the problems involved. One thing is certain, that the founding of such a research institution is the true scientific way to provide for the future, in assurance that the natural difficulties will finally yield to human persistency and intelligence.**

In a report to the international committee, Southport, England, 1903, Sir Norman Lockyer presented a most interesting review and discussion of the subject of simultaneous solar and terrestrial changes (Science, Nov. 13, 1903). He called attention to the fact that "there are many cases recorded in the history of science in which we find that the most valuable and important applications have arisen from the study of the ideally useless," and that "long-period weather forecasting, which at last seems to be coming into the region of practical politics as a result of the observation of solar changes, is another example of this sequence." After referring to the knowledge possessed by the ancients of changes in the sun, and to sun spots and a magnetic force which acts upon a needle, which seem to have been known to the ancient Chinese, he passes to more modern inquiries, that date from the times of Galileo and Kepler, which have furnished telescopic observations of the spots on the sun and revealed by spectrum analysis the chemistry of the sun and of its spots, and have also enabled us to study daily other phenomena, the solar prominences, which will in all probability turn out to be more important for practical purposes than the spots themselves.

He quotes from Philosophical Transactions, London, 1801, page 265, an article by Sir William Herschel, which is particularly interesting, not only by reason of the prominence in scientific history of the writer but from the fact that an association of the variation in sun spots with the price of corn and wheat has resulted in popular discussions of the suggestion and misinterpretations of the language and meaning of the author during a period of more than one hundred years. Although Herschel had but little observational data upon which to make comparisons between cycles in the solar changes and the prices of corn and wheat, his argument regarding the influence of the sun on vegetation and his inference that variations in the quantity of light and heat emitted from the sun that are associated with the appearance and disappearance of sun spots were favorable or unfavorable to vege-

tation have been given respectful consideration by succeeding generations of scientists. The article referred to is as follows:

The first thing which appears from astronomical observations of the sun is that the period of the disappearance of spots on the sun are of much greater duration than those of their appearance.

With regard to the contemporary severity and mildness of the seasons, it will hardly be necessary to remark that nothing decisive can be obtained. An indirect source of information, however, is opened to us by applying to the influence of sunbeams on the vegetation of wheat in this country. I do not mean to say that this is a real criterion of the quantity of light and heat emitted by the sun, much less will the price of this article completely represent the scarcity or abundance of the absolute produce of the country.

On reviewing the period 1650–1713, it seems probable from the prevailing price of wheat that some temporary scarcity or defect of vegetation has generally taken place when the sun has been *without* those appearances which we surmise to be symptoms of light and heat.

To those acquainted with agriculture who may remark that wheat is well known to grow in climates much colder than ours, and that a proper distribution of rain and dry weather are probably of much greater consequence than the absolute quantity of light and heat derived from the sun, I shall only suggest that those very circumstances of proper alternations of rain and dry weather and wind, etc., favorable to vegetation, may possibly depend on a certain quantity of sunbeams being supplied to them.

About 1870 and 1871, Doctor Meldrum, director of the observatory at Mauritius, concluded that the number of cyclones in the Indian Ocean and the number of wrecks which came into the harbor of Maritius indicated the number of spots on the sun; that, in fact, the maximum number of cyclones was associated with the maximum number of sun spots. In the West Indies Poey found that, as a rule, the maxima of storms fall from six months to two years, at the most, after the years of maxima of solar spots; that out of twelve maxima of storms, ten coincide with maxima of spots, and that out of five minima of storms, five coincide with minima of spots.

## CONCLUSIONS.

A review of the foregoing remarks and opinions regarding the application of past and present astronomical and meteorological knowledge to the theory and practice of long-range weather forecasting leads to the following conclusions:

1. That systems of long-range weather forecasting that depend upon planetary meteorology; moon phases, cycles, positions, or movements; stellar influences, or star divinations; indications afforded by observations of animals, birds, and plants, and estimates based upon days, months, seasons, and years have no legitimate bases.

2. That meteorologists have made exhaustive examinations and comparisons for the purpose of associating the weather with the various phases and positions of the moon in an earnest endeavor to

make advances in the science along the line of practical forecasting, and have found that while the moon, and perhaps the planets, exert some influence upon atmospheric tides, the influence is too slight and obscure to justify a consideration of lunar and planetary effects in the actual work of weather forecasting.

3. That the stars have no appreciable influence upon the weather.

4. That animals, birds, and plants show by their condition the character of past weather, and by their actions the influence of present weather and the character of weather changes that may occur within a few hours.

5. That the weather of days, months, seasons, and years affords no indications of future weather further than showing present abnormal conditions that the future may adjust.

6. That six and seven day weather periods are too ill-defined and irregular to be applicable to the actual work of forecasting.

7. That advances in the period and accuracy of weather forecasts depend upon a more exact study and understanding of atmospheric pressure over great areas and a determination of the influences, probably solar, that are responsible for normal and abnormal distributions of atmospheric pressure over the earth's surface.

8. That meteorologists are not antagonistic to honest, well-directed efforts to solve the problem of long-range forecasting; that, on the contrary, they encourage all work in this field and condemn only those who, for notoriety or profit or through misdirected zeal and unwarranted assumptions, bring the science of meteorology into disrepute.

9. That meteorologists appreciate the importance to the world at large of advances in the period of forecasting and are inclined to believe that the twentieth century will mark the beginning of another period in meteorological science.

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